August 1996

Mobile Radio Technology™

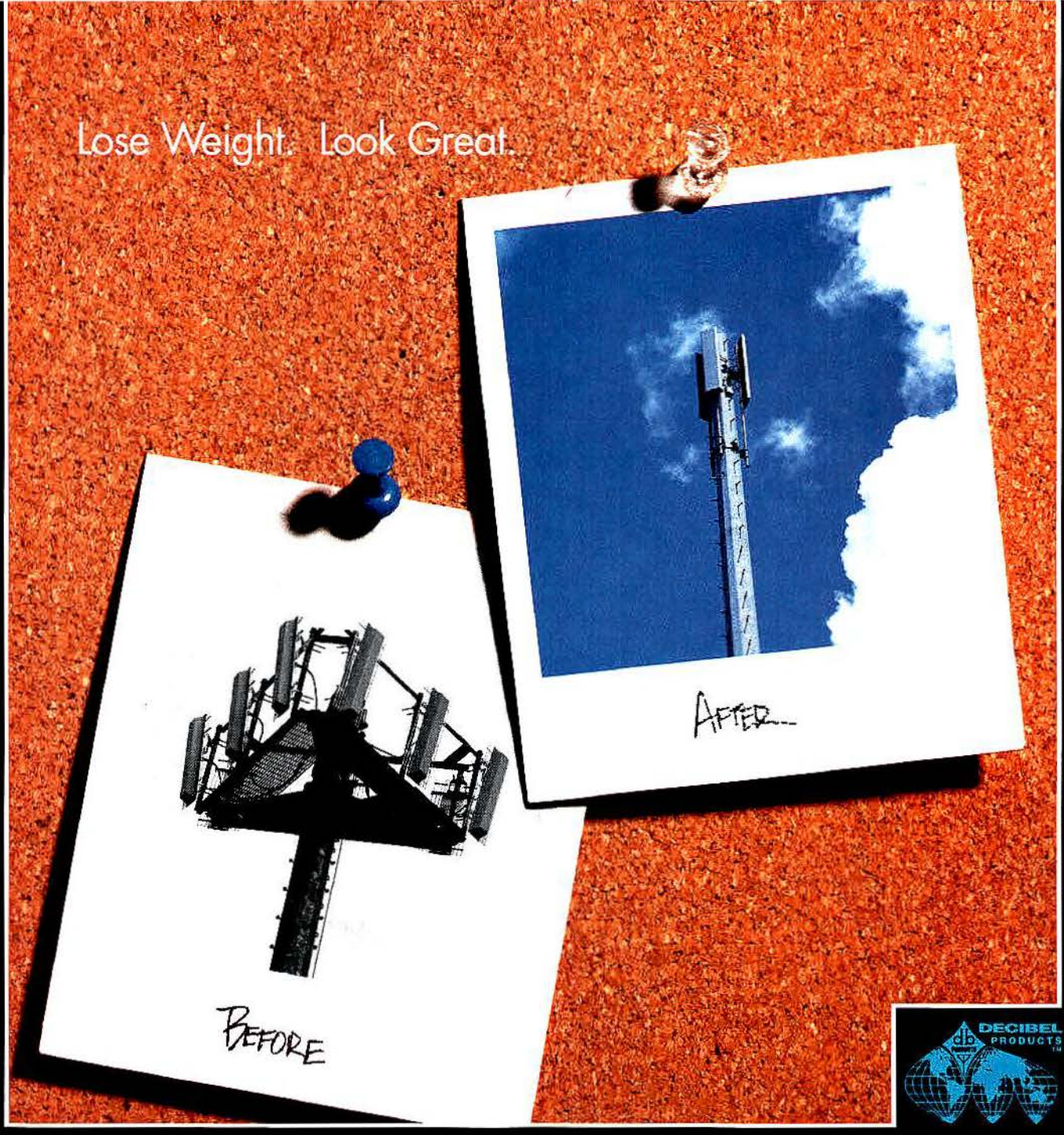
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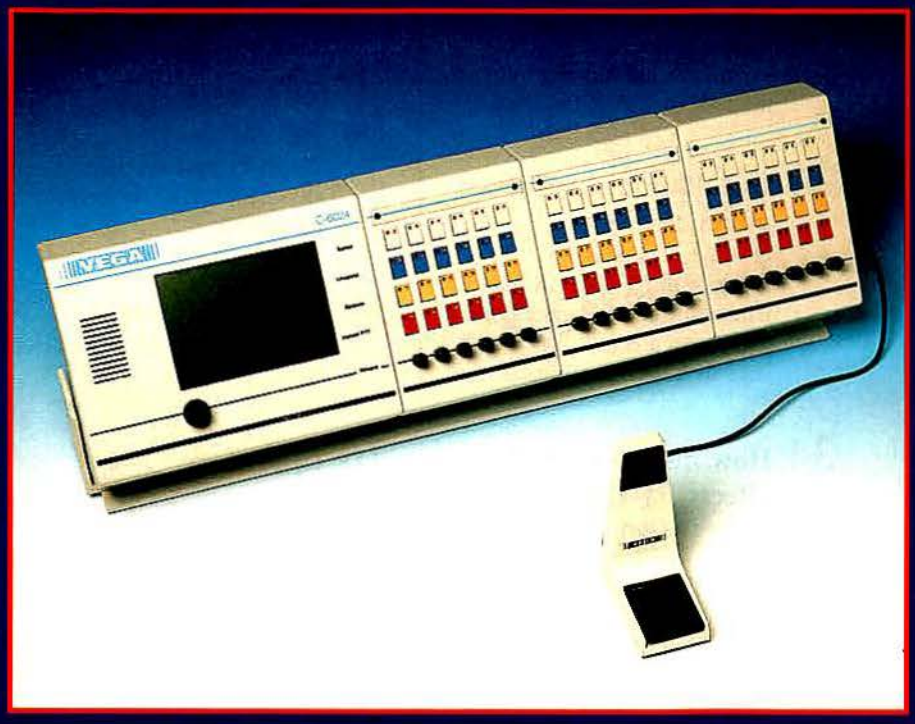
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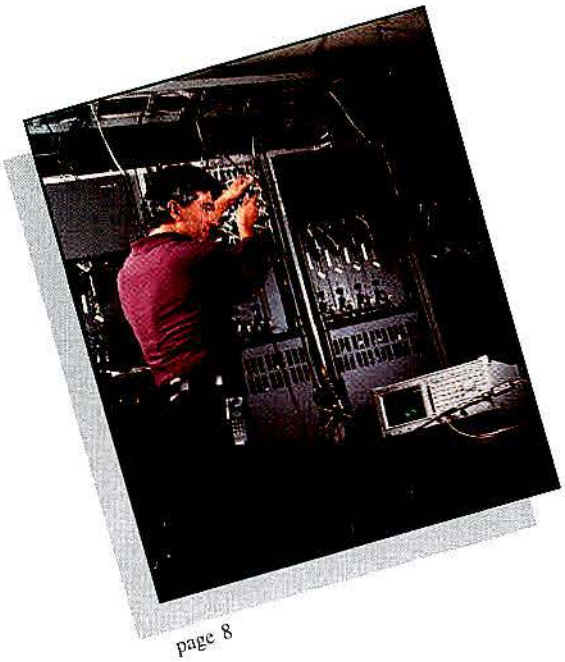
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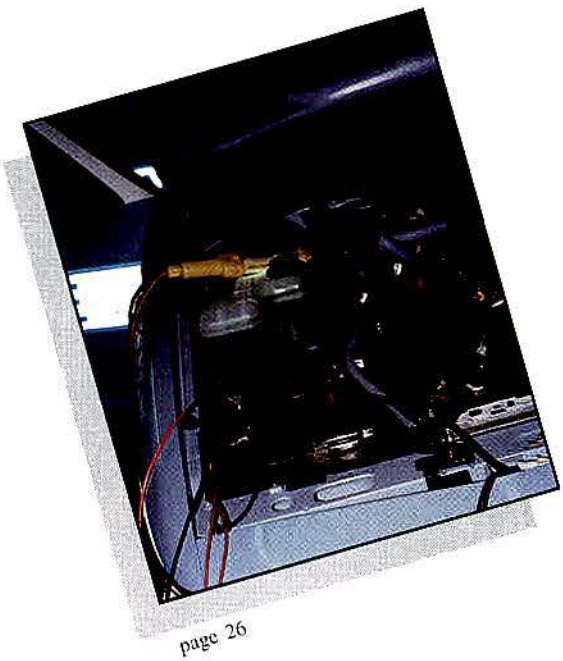
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Did Nextel receive special treatment with ESMR license grants?



Attorney Dennis C. Brown of the Washington, DC-based law firm of Brown and Schwaninger has requested the FCC to cancel certain enhanced specialized mobile radio (ESMR) licenses held by Nextel Communications, McLean, VA, and to dismiss the applications on which the license grants were based. Although the law firm represents many small businesses that compete with Nextel, no clients were named in the petition filed June 25, 1996, by Brown. Robert H. Schwaninger Jr., Brown's partner, is our regulatory consultant and columnist.

If the relief sought by the petition is granted, it is possible that licenses for thousand of channels held by Nextel would be cancelled, perhaps freeing them for use by other SMR businesses. Nextel has not constructed repeater stations for a large portion of the channels for which it holds licenses, some of which would be affected by Brown's petition.

Brown examined a random selection of the large number of ESMR license applications granted on Oct. 31, 1995, to Nextel, its subsidiaries and companies that since have merged with Nextel. His analysis finds that at least 71% of the sampled applications are defective on their faces and should not have been granted.

Brown requested 42 applications; the FCC supplied 35, giving no reason for not supplying six of the seven that were omitted; Brown found 25 of the 35 applications were defective, a rate of 71%. The average number of channels per application is 150. An estimated 36,000 frequencies are represented on the 600 pages that list licenses granted to Nextel, its subsidiaries and acquired companies on Oct. 31, 1995. If the deficiency rate of 71% affects them all, then about 26,000 channels would be affected.

Application defects

Here are some of the defects that Brown found:

1. Required engineering documentation and evidence of frequency coordination had not been filed.

2. Applications for which a waiver would have been required but for which no waiver was requested and for which no fee had been paid at the time of the filing of a waiver request.

3. Applications for which no waiver was *requested*, but for which a waiver was *granted* without the payment of a waiver request filing fee.

4. Applications that did not demonstrate compliance with the interference criteria that were in effect at the time that the applications were processed.

5. An application that should have been barred by the freeze on filing of applications.

6. An application for which the location of the proposed station could not be ascertained within the application.

For any applications that are defective, there is ample precedent to indicate that the FCC should cancel the corresponding licenses and dismiss the applications, thereby giving Nextel no opportunity to cure the defects. That is the relief that Brown seeks.

Can't have it both ways

One important point is that, one way or another, a fee should have been paid. Either an application has frequency coordination and the coordination fee is paid, or an application includes a waiver request and a waiver fee is paid. Apparently, neither fee was paid with these applications.

It is uncertain exactly how fees would have been charged for these applications, and exactly what proportion of the applications for licenses for the 36,000 channels were submitted without proper fees. The following estimates use the 71% proportion, or 26,000 channels, as an example.

If the FCC had applied its $105 waiver fee to each license for an average of 150 frequencies each, the fees for 26,000 channels would have amounted to about $18,000. If it had applied the fee to each channel, the fees would have reached about $2.7 million. The FCC usually is a real stickler for dismissing applications that are not accompanied by the necessary fees. Why were these applications processed?

Frequency coordinators

At least two frequency coordinators, the Personal Communications Industry Association (PCIA) and the Industrial Telecommunications Association (ITA), offer coordination services for ESMR applications. At the minimum $17 per frequency per site charged by one particular frequency coordinator, PCIA, the coordination fee would amount to $442,000 for 26,000 frequencies. At the maximum $150 per frequency per site charged by PCIA and ITA, the fee would be $3.9 million. Were frequency coordinators deprived of revenues to which they otherwise would have been entitled?

ESMR channels are given a value of $50,000 each by business brokers. Using that figure, the 26,000 channels that Brown's analysis indicates could be subject to license cancellation are worth $1.3 billion.

Imagine that you operate a small SMR business, and you applied for some additional frequencies.

If your application required a waiver, but you didn't pay the waiver fee, would it be granted?

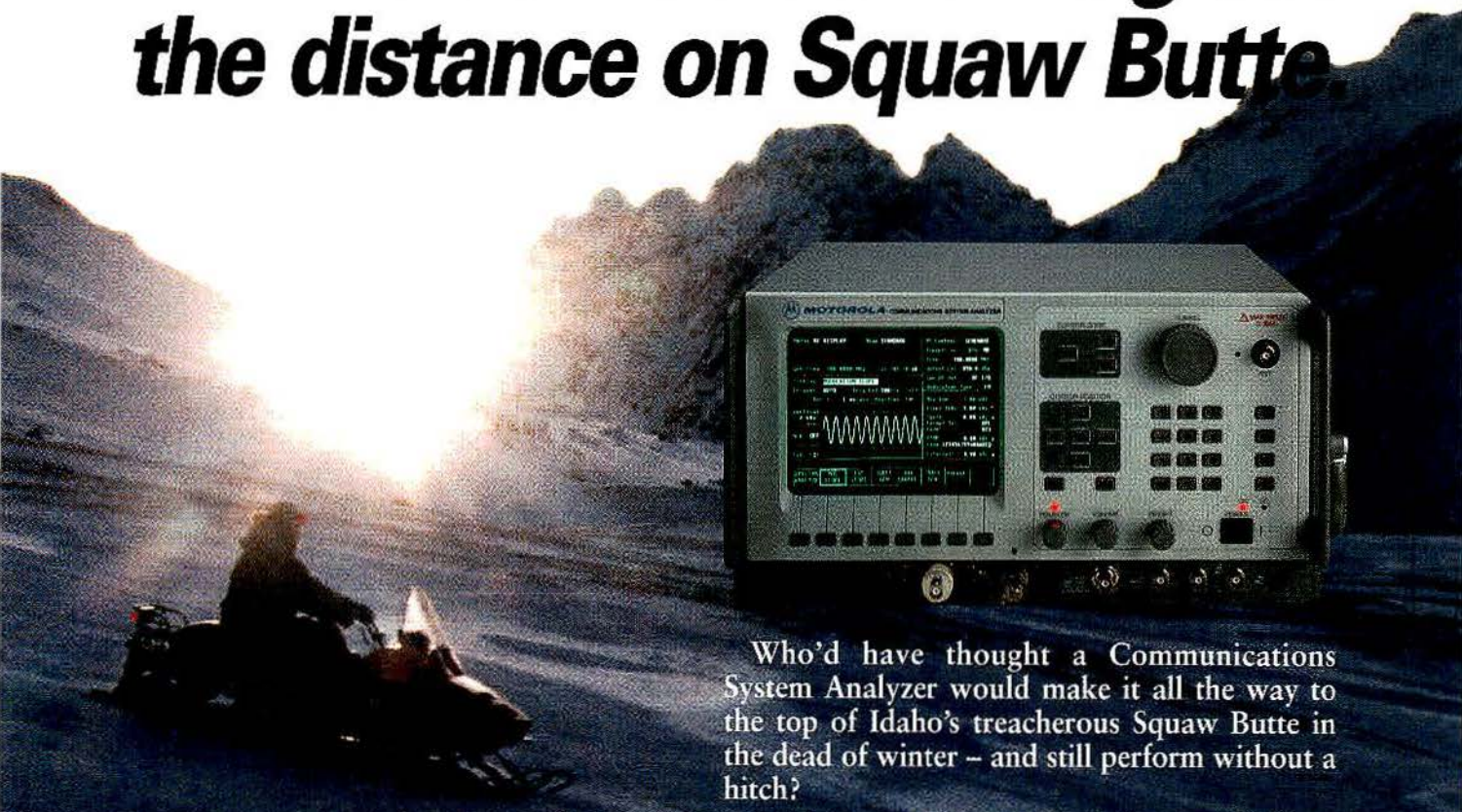
If your application required frequency coordination, but you didn't submit evidence of such coordination, would it be granted?

If your application required engineering exhibits to support proposed short-spacing to other radio communications facilities, but you didn't include such exhibits, would it be granted?

If these applications for thousands of channels required waiver requests, frequency coordination or engineering exhibits, not to mention the necessary fees, and they were submitted without them, why were they granted?

—Don Bishop

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Calendar

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11–15—International Association of Public-Safety Communications Officials (APCO) National Conference, San Antonio, TX. Contact: 800-949-2726.

September

16–17—Pre -PCS CDMA workshop on CDMA System Design, Engineering and Optimization, sponsored by Wireless Institute of Technology, San Francisco, CA. Contact: 510-490-6459; E-mail 2026500@mcimail.com.

19–21—Personal Communications Showcase, sponsored by the Personal Communications Industry Association, Moscone Convention Center, San Francisco. Contact: 800-326-8638.

October

30–Nov. 1—WirelessWorld Conference and Exposition, sponsored by *Cellular Business* and *Mobile Radio Technology* magazines, Orange County Convention/Civic Center, Orlando, FL. Contact: Susan Link, 913-967-1969.

November

22—Radio Club of America, Communications Symposium, 87th Anniversary Dinner and Awards Presentation, New York Athletic Club, New York. Contact: Ron Formella, 201-652-6811.

18–19—AMTEX, the American Mobile Telecommunications Association's Marketing and Technology Conference and Exposition, Intercontinental Hotel, Miami. Contact: 202-331-7773.

18–20—First International Congress on Commercial Trunked Radio, sponsored by the International Mobile Telecommunications Association, Intercontinental Hotel, Miami. Contact: 202-331-7773.

1997

March

3–5—Wireless, sponsored by the Cellular Telecommunications Industry Association, Moscone Convention Center, San Francisco. Contact: 202-785-0081.

23–26—Energy Telecommunications and Electrical Association, New Orleans Convention Center, New Orleans. Contact: 214-235-0655.

April

22–24—International Wireless Communications Expo, co-sponsored by *Mobile Radio Technology*, Las Vegas Sands Convention Center, Las Vegas. Contact: 800-288-8606.

May

5–7—Vehicular Technology Conference, sponsored by IEEE Vehicular Technology Society, Hyatt Regency at Civic Plaza, Phoenix, AZ. Contact: Wendy Rochelle, 908-562-3870; Fax 908-981-1769.

June

2–5—Supercomm, sponsored by USTA and TIA, New Orleans Convention Center, New Orleans. Contact: 202-326-7300.

16–20—UTC National Conference & Exhibition, sponsored by UTC, The Telecommunications Association, Oregon Convention Center and Red Lion Lloyd, Holiday Inn, and Travelodge Hotels, Portland, OR. Contact: 202-872-0030.

September

10-12—Personal Communications Showcase, sponsored by the Personal Communications Industry Association, Dallas Convention Center, Dallas. Contact 800-326-8638.

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Frequency domain reflectometry vs. time domain reflectometry

Here are the fundamentals of two measurement technologies and a nuts-and-bolts look at the practical implications for RF antenna systems.

By Ken Harvey

RF cable and antenna testing is increasingly important to sustain performance quality and to reduce maintenance costs. Frequency domain reflectometry (FDR) is rapidly gaining popularity in applications above 200MHz. How does FDR technology stack up against the traditional cable testing technique, time domain reflectometry (TDR)?



Harvey is product marketing manager, Anritsu Wiltron, Morgan Hill, CA.

Technical seminars, applications notes and analysis software covering antenna system measurements are available free from the company.

The simplified drawing in Figure 1 below identifies several common devices on a typical antenna tower. The drawing illustrates how both TDR and FDR techniques rely on the scientific principle that no transmission line component is a perfect impedance match. At any impedance mismatch, some of the energy of an incident signal is reflected backward toward the source. If these reflections are excessive, the antenna system does not operate properly.

Several important factors should be considered when testing RF antenna systems. First, TDRs have been in common use for many years and, as a necessary and practical consideration, experienced technicians have adopted clever tricks and techniques to interpret the displays. Historically, TDRs have been smaller and much less expensive than FDR-based analyzers. FDR systems were only purchased by technicians who needed the higher FDR frequency coverage for microwave applications. Although there no longer are size and price discrepancies, the fundamental technical differences remain. (See Table 1 on page 9.)

Stimulus signal

Both TDR and FDR have similar acronyms, and both test for excess signal reflections in RF cables, but there the similarities end. The FDR technique sweeps the antenna system at RF frequencies. A TDR injects dc pulses. Figure 2 on page 9 shows how the different stimuli respond in a typical RF antenna.

The RF sweep used by FDR is sensitive to RF problems and accurately identifies the return loss of the antenna. A TDR's pulsed dc stimulus reflects little energy at RF faults. Further, almost 100% of the TDR's source energy is reflected by the antenna or any other in-line, frequency-selective device such as frequency combiners, filters or quarterwave lightning arrestors. This behavior is predicted according to the spectral energy density of the

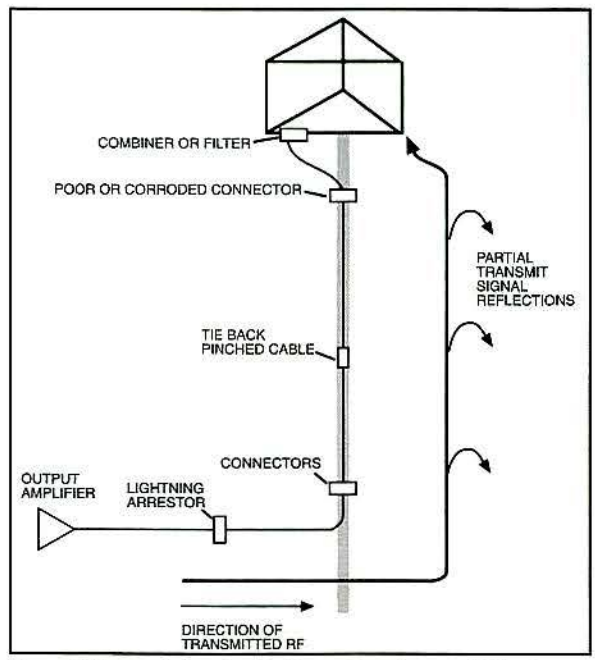


Figure 1. Transmission line faults, such as damaged lightning arrestors, poor connectors, pinched cables and water penetration, reflect the transmitter's output energy backward toward the source.

stimulus sources shown in Figure 3 below right. The TDR's spectral content is splattered across a wide frequency range. The spectral magnitude of the output pulses tends to roll off rapidly at high frequencies. Typically, less than 2% of a TDR's pulse energy is distributed in the RF frequency ranges.

FDR techniques generate an RF sweep that includes only the frequency range selected by the operator, allowing frequency-selective characteristics to be displayed clearly. Measurements include return loss (or standing wave ratio, SWR) vs. frequency and return loss (or SWR) vs. distance. Instruments with frequency ranges as high as 1,200MHz and 3,300MHz are available for $4,000 to $7,000. Coverage to 8.6GHz and 20GHz typically costs $22,000 to $37,000.

The need for higher bandwidth drives the requirements for more accurate TDR time bases, faster pulse generators and faster sampling rates. These requirements drive costs. Several 100MHz-bandwidth TDRs are available today for $3,500 to $4,500. Models with higher bandwidths typically exceed $8,000 to $12,000. Bandwidth is determined by the TDR's pulse rise time. A TDR's pulse generator injects pulsed dc signals or fast-rising dc steps into the antenna cable. The equation in Figure 4 on page 10 is a good estimation for both.

How can a TDR test the antenna system when the lightning arrestor is one of the new quarterwave types instead of the standard gas-discharge capsule? How can the TDR test through duplexers or interference rejection filters? Simply stated, the TDR cannot test bandpass RF signal devices. Thus, TDRs tend to identify dc parametric values that identify performance characteristics below 100MHz to 200MHz. In contrast, the FDR technique pinpoints RF performance information throughout the RF and microwave ranges.

Table 1—Comparsion of FDR and TDR

	Frequency Domain Reflectometry	Time Domain Reflectometry
Stimulus signal	RF sweep	dc pulses
Immunity to interference	High	Poor
Compensates for cable insertion loss	Yes	No
"Dead zone" problem	No	Yes
Measures SWR/return loss	Yes	No
Return loss accuracy		
Directivity	Excellent	Poor at RF
dB Linearity	Excellent	Not linear
Source and load match	Excellent	Poor at RF
Traceability	NIST	none for RF
Measures antennas, filters and duplexers	Yes	No
Measures waveguide	Yes	No
Measures coaxial cable	Yes	Yes
Measures twisted pair cable	Requires special adapter	Yes
Distance accuracy	Inherently accurate	Limited by time base
Distance resolution	Frequency dependent	High, typically
Finds open-circuit or short-circuit faults	Yes	Yes
Typical price	$4,000 to $60,000	$1,500 to $20,000

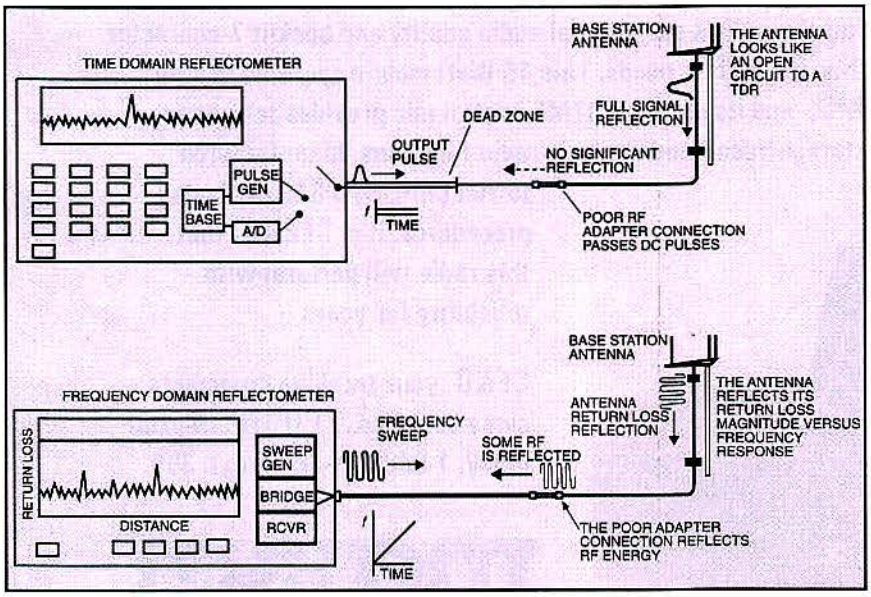


Figure 2. The stimulus energy of the RF sweep from FDR and the dc pulse from TDR propagates differently.

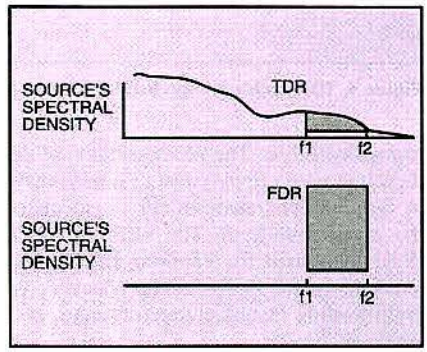


Figure 3. The FDR sweep is confined to the operating frequency of the cable and antenna.

Distance accuracy

Again referring to the example in Figure 2, as reflected signals return at 60% to 88% of the speed of light, the TDR's fast-sampling analog-to-digital (A/D) converter digitizes the reflected pulse amplitudes. Synchronization for the generator and digitizer is controlled by a time base, the precision of which decides the distance accuracy in the resulting display. It is no wonder that the most accurate TDR-based instruments come from leading oscilloscope manufacturers.

The FDR technique requires that a frequency oscillator feed a swept-frequency signal into the transmission line. A radio frequency receiver measures the interference pattern generated when the swept RF source output signal adds and subtracts with reflected signals from faults and other reflective characteristics within the tested

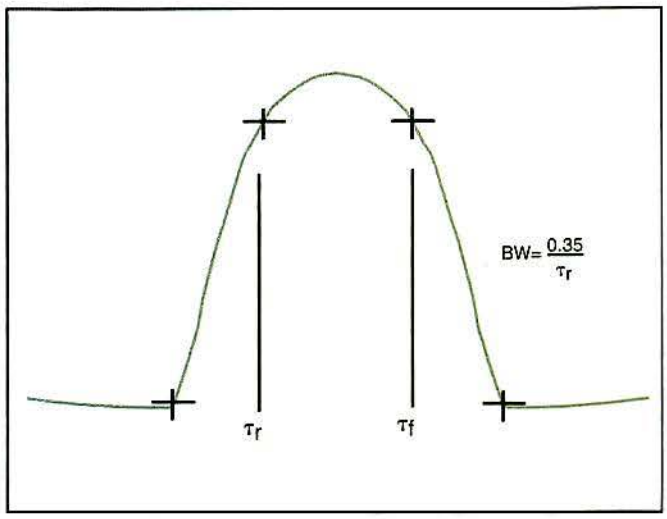


Figure 4. TDRs achieve high bandwidth with faster pulse rise time.

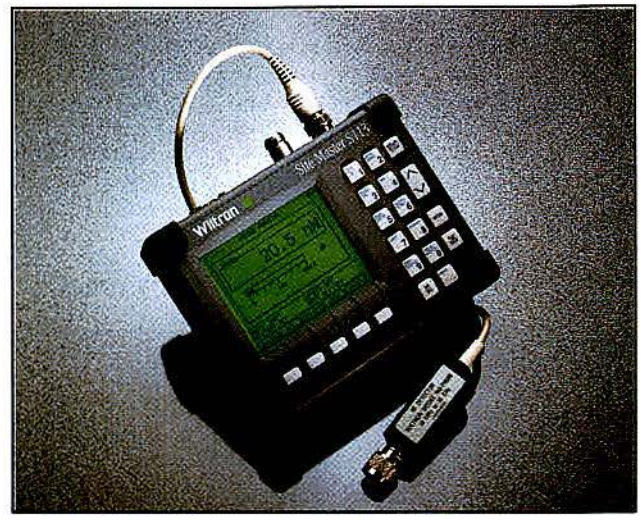


Photo 1. FDR instruments, such as this Site Master with detector, include additional RF measurements such as RF power.

transmission line. The vector addition of the signals creates a ripple pattern vs. frequency. A fast Fourier transform (FFT) calculates the *distance-to-fault*. The identical block diagram is used for RF network analysis. Predictably, the FDR-based products come from leading manufacturers of vector network analyzers.

The number of ripples in the return loss (or power) vs. frequency display is directly proportional to the electrical distance to the reflective point on the transmission line, as shown in Figure 5 on page 16. This electrical distance indication is inherently accurate and suffers no accuracy degradation due to TDR-type time base controls.

The electrical distance is related to physical distance according to the propagation velocity, *kp*, similar to the TDR's velocity correction factor for the same property. Cables with different dielectric types maintain different electrical propagation speeds. In the following equation, the integer number of displayed ripples, *n*,

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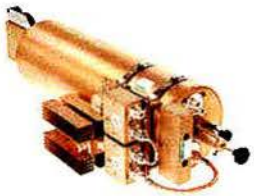
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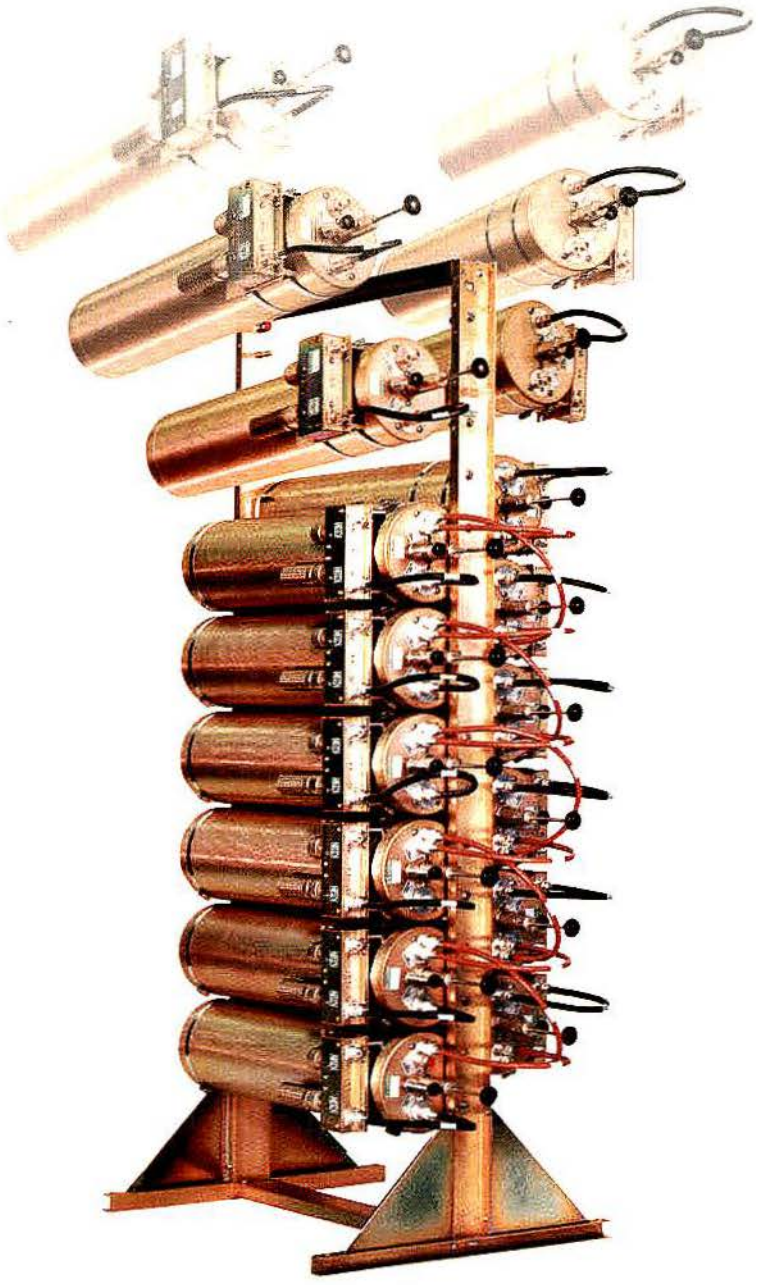
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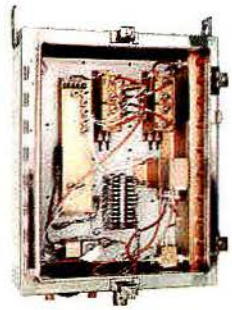


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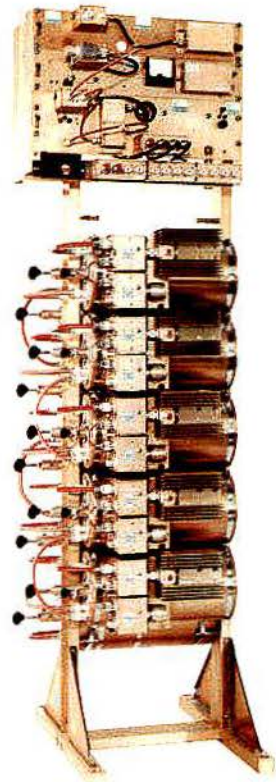


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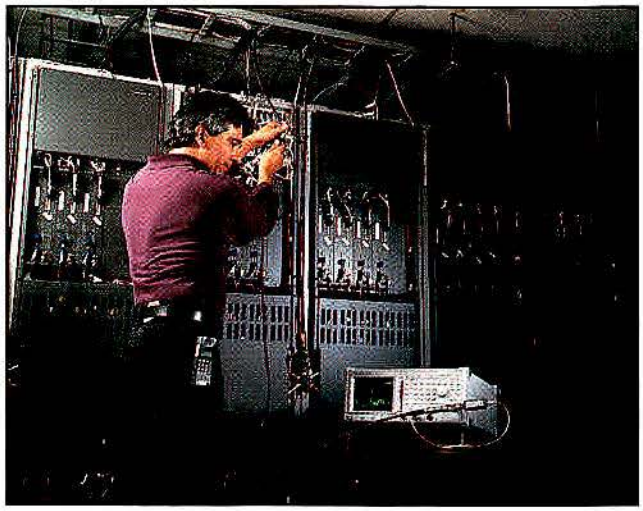


Photo 2. FDR techniques reject external RF interference at "live sites" such as this NAMPS cell site, where two competing service providers have co-located base station antennas.



Photo 3. FDR techniques accurately compensate for cable insertion loss. Antenna return loss is clearly displayed.

relates to fault location, L, according to:

$$L = \frac{n \times c \times kp}{2 \times \Delta f}$$

where

c = speed of light

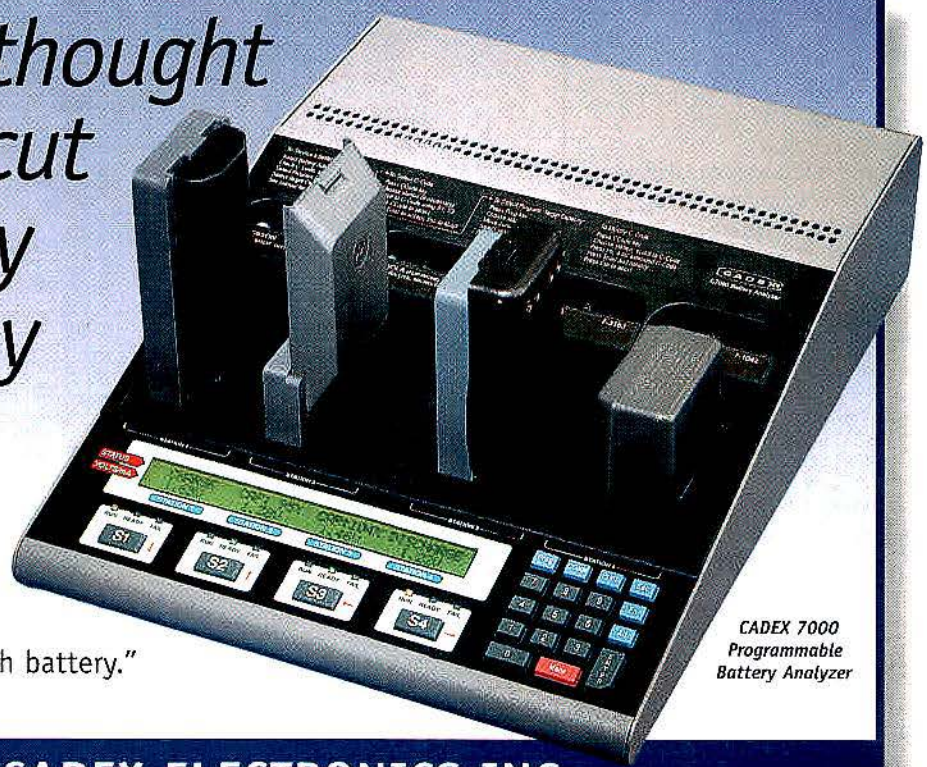
Δf = frequency sweep width

Thus, the FDR analyzer's distance accuracy is determined by knowledge of the cable's propagation velocity.

In general, TDRs have better distance resolution when testing short cables. When cables are less than 10 feet long, the FDR technique requires a wide frequency sweep to achieve adequate resolution because FDR's fast Fourier transform requires several frequency display ripples before adjacent problems are isolated. This is the primary reason why TDRs are preferred for

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short cables that cannot exceed 100MHz frequency range. A good example is a twisted pair cable for computer local area networks (LANs). The FDR approach is better for coaxial cables, as commonly are used with Ethernet-based LANs.

Improving FDR distance resolution is the reason design engineers will use 67GHz-to-110GHz coaxial vector network analyzers (VNAs). The frequency range is needed to isolate segments of the circuit designs to sub-millimeter distances using the VNA's "time domain" mode.

If we consider all the factors involved in a typical antenna system measurement, including not only the accuracy of TDR and FDR techniques, but also the ability to actually measure the physical length of an installed cable, accuracy requirements are not particularly strenuous. Field service technicians need accuracy and resolution to a few feet for transmission lines from 10 to 1,000 feet long. This is easily accomplished by both TDR and FDR techniques.

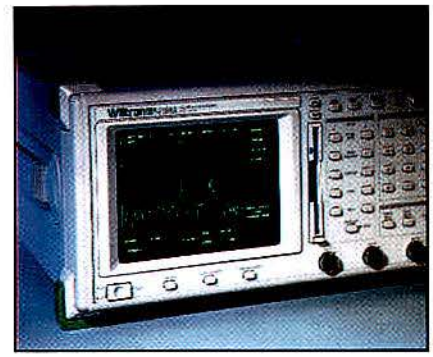


Photo 4. The 54100A series network analyzers for waveguide and/or coaxial FDR testing are available at frequencies to 3GHz, 8.6GHz, 20GHz, 40GHz, 50GHz, 75GHz and 110GHz.

Return loss (SWR) accuracy

FDR techniques are National Institute of Standards and Technology (NIST) traceable and include several RF measurements such as insertion loss, gain and RF power in addition to return loss and SWR. TDRs do not display RF return loss nor any other RF parameter. Theoretically, the reflected responses from an ideal pulsed dc signal stimulus can be converted into frequency domain information by integrating the pulse reflections over the interval of reflection from the device. (See Photo 1 on page 10.)

Today, fast Fourier transform of TDR data is the subject of advanced research. Some limited functionality is available in some GHz-rate oscilloscopes. Practical limitations for low-cost field instruments include size, sample rates, time base control and traceable reference calibration standards. Despite commercial claims of high equivalent bandwidth, pulse TDRs do not provide sufficient effective directivity for accurate RF frequency tests such as return loss and insertion loss.

By contrast, the accuracy of the FDR technique is traceable and well-defined in terms of directivity and measurement linearity. Source match and load match of modern FDR analyzers are excellent, reducing these error sources to negligible levels.

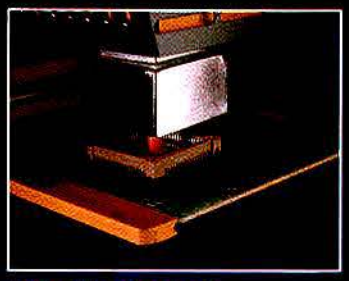
Further, the FDR methods do not suffer from the "dead zone" problem common to TDR implementations. The dead zone results from the time required for the TDR's A/D sampler to begin sampling after the dc pulse generator injects a pulse.

If it's important to reduce costs and improve quality through preventive maintenance, return loss accuracy to less than ±1.0dB is an absolute requirement. Accuracy determines test repeatability, which

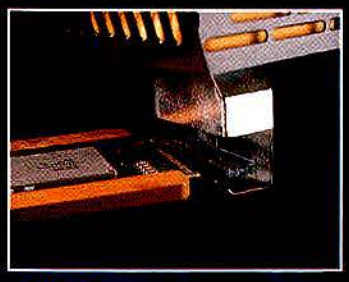


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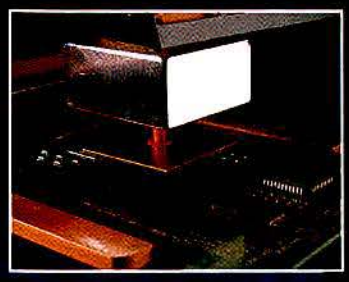
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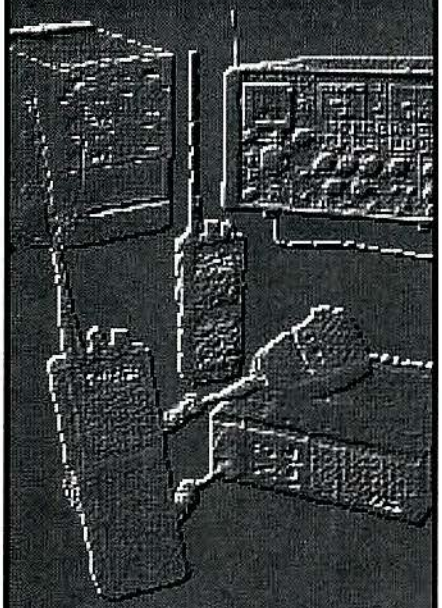
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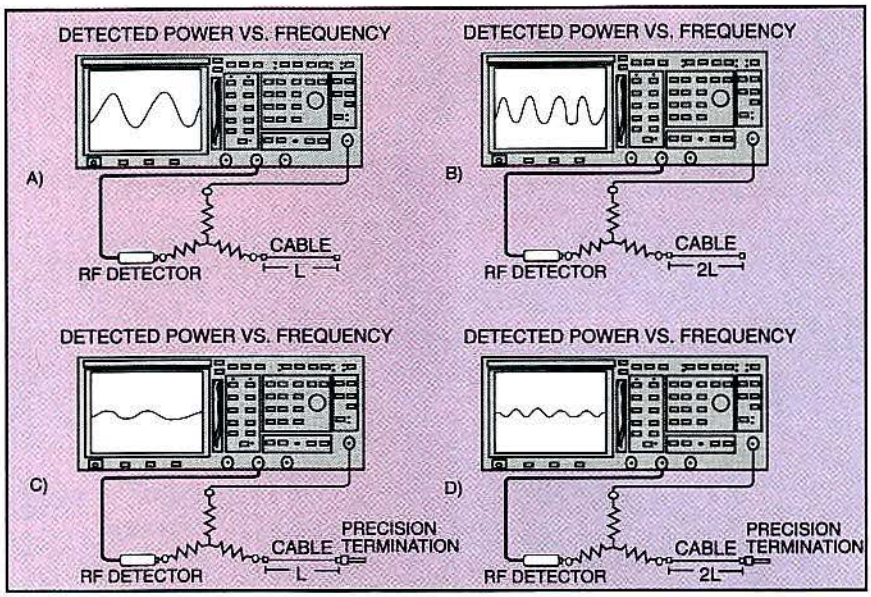


Figure 5. Referring to a) and b), as the distance to the open-circuit condition increases, more ripples appear on the analyzer display. Referring to c) and d), when the open circuit is replaced with a termination, the amplitude of the ripple is attenuated.

determines the ability to spot the initial symptoms of the problem. Under the failure prevention philosophy, return loss accuracy is much more important than distance accuracy.

Sensitivity

Sensitivity is excellent on both FDR and TDR analyzers; however, they're sensitive to different characteristics. Whereas the TDR is sensitive to lumped-dc parametric characteristics, it is likely to miss RF characteristics such as corrosion, slight pin gaps and damaged RF components. The TDR has severe difficulty "seeing" past any RF component with a passband characteristic, such as filters, duplexers, quarterwave lightning arrestors and antennas. Figure 6 above shows the basic limitation of TDR techniques to frequency-selective performance problems. This problem is caused by the large proportion of dc spectral content of the TDR's stimulus signal.

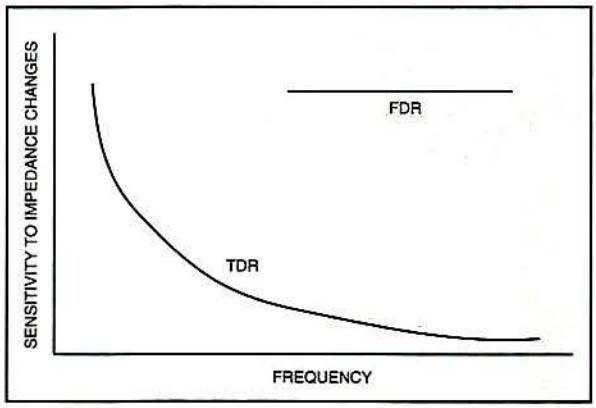


Figure 6. TDR sensitivity degrades with increasing bandwidth. FDR sensitivity is high at RF frequencies.

The FDR technique is highly sensitive to any dimensional tolerance change within the RF conductor path. Even a tiny variation in return loss, such as a connector changing from 25dB to 22dB return loss, is clearly detected. Although a 22dB figure would still pass specification, it is important to identify the change in impedance. If the connector has changed, then the weather seal is also likely to have changed. Over time, water will seep under the seal and destroy the cables. During this time, the cell site coverage area will contract. Holes within the coverage area of the transmitter will expand, reducing service quality. The connector will corrode and form a dissimilar metal-to-metal contact. This "diode" will cause passive intermodulation distortion and adjacent channel power problems for digitally modulated signals.

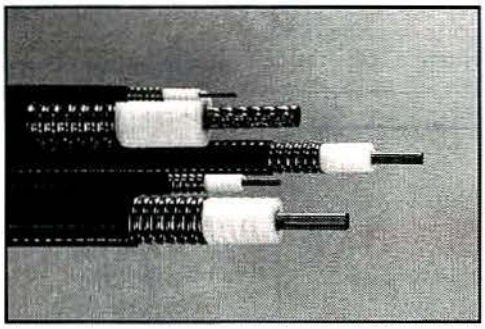
My company takes the position that it is better to find these small problems before complete failure causes outage and expensive repairs. Because of the lack of adequate sensitivity and RF accuracy, TDR techniques amount to a "fix-after-failure" service philosophy. Only FDR techniques provide the ability

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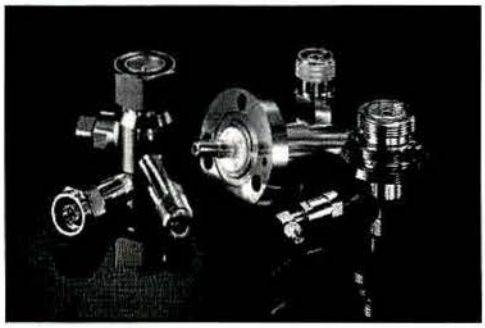
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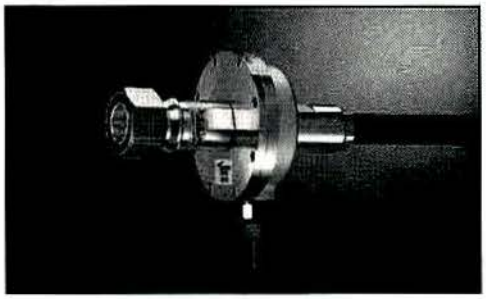
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to implement preventive maintenance plans.

Immunity to interference

For RF system design, zoning and economic reasons, RF transmitter antennas are frequently co-located. The explosion in wireless communications implies that the sources of RF interference will increase in the future, not decrease. TDRs, being baseband sampling devices, will produce extraneous readings in the presence of nearby transmitters. Averaging helps, but if the interference is above a few milliwatts, TDRs frequently fail to measure anything.

Modern FDR analyzers are built to reject interference by using ac detection or auto-zeroing and advanced designs such as phase-tracking vector receivers and spread-spectrum techniques. The FDR measurements must be immune to external interference so tests can be performed without shutting the site's transmitters down. Site locations at hill top "antenna farms" can be tested even with very high ambient RF energy into the antenna. (See Photo 2 on page 12.)

Compensates for cable insertion loss

FDR tests the cable and antennas at RF, their frequency of operation. By measuring RF characteristics directly, FDR provides a clear performance indication. By virtue of using the same RF frequencies as these devices, FDR techniques easily measure the antenna system and accurately reflect the return loss performance of each device versus distance.

FDR also compensates for the insertion loss of the RF cables; thus, the antenna return loss display is not perturbed by the cable's inherent insertion loss. (See Photo 3 on page 12.) This allows easy identification of problems, such as moisture collection or antennas damaged by lightning, at the top of the tower.

Commercial TDRs do not compensate for RF insertion loss values because the cable's RF insertion loss characteristics are frequency-dependent.

Test device types

FDR techniques have a clear advantage testing antennas, filters, duplexers and waveguide. Because these devices are found in antenna systems, FDR techniques are also preferred for coaxial antenna feeds. When checking coaxial cable for length, TDR or FDR is adequate. If return loss is also tested, FDR is clearly a better choice.

Testing twisted pair cable is typically best performed by a TDR device because twisted-pair cables have a limited frequency range, reducing the resolution of any FDR display. Further, twisted-pair cables are typically used for baseband digital signals, not RF. Coaxial cable, such as those for Ethernet LANs, can be adequately tested with either TDR or FDR instruments.

In short, TDRs are appropriate for baseband dc tests and FDR techniques for RF device tests.

Commercial FDR products

The 25MHz-to-3,300MHz Site Master (Photo 3) solves several nagging problems.

The explosion in wireless communications implies that the sources of RF interference will increase in the future, not decrease.

First, the synthesized source and novel phase tracking receiver technology reject ambient interference. Second, vector network analyzer measurement techniques ensure test accuracy. Third, FDR technology is used to identify very small changes in RF impedance versus distance. Finally, the battery-powered package is lightweight and rugged.

In addition to return loss, SWR and distance-to-fault, the 54100A network analyzers also measure insertion loss, gain, precision return loss, directivity, power and group delay.

Summary

FDR-based distance-to-fault techniques can detect minute problems. If problems such as vapor intrusion, loose connectors, antenna bandwidth drift, corroded conductors or damaged lightning arrestors can be identified before severe damage/failure occurs, corrective action can be taken. The timely replacement of the problem component mitigates the need for replacement of the complete antenna system later.

FDR finds potential problems quickly and reliably, allowing cellular service professionals to implement preventative maintenance plans and reduce costs per cell expenses. As a trouble shooting tool, FDR techniques pinpoint damage and impending failure conditions.

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One-way paging to NPCS: Strategies for migration

Carriers can minimize the risk of narrowband personal communications services (NPCS) deployment by using wireless messaging transfer protocol to share another network or by using ReFlex protocol to add a return channel.

By Steve Olsen

Several American paging companies spent a total of more than $1 billion for radio frequency (RF) licenses in the 1994 FCC spectrum auctions. Those large, public companies now are pursuing the burgeoning narrowband personal communications services (NPCS) market aggressively.

As the next evolutionary step in paging, NPCS promises to deliver many advanced wireless messaging services such as wireless E-mail, two-way messaging and voice messaging. Building a NPCS network to market such services will require a substantial investment. So how does a small- or medium-size carrier with limited human and capital resources enter the NPCS market?

Many carriers are reviewing business plans for the next round of narrowband auctions, the MTA/BTAs (major trading areas/basic trading areas), which are commencing in late 1996. Carriers are challenged by the need to pursue new NPCS revenue opportunities while they protect their one-way paging business. Carriers are advised to position themselves for NPCS by carefully choosing technologies and services that allow the most economical migration from one-way paging to NPCS. The central question is whether new one-way paging infrastructure purchased today will allow migration to NPCS. With proper system planning, the existing transmitters, control systems, distribution and switches can be used for NPCS as well as for one-way paging.

Olsen is NPCS sales engineer at Glenayre, Vancouver, British Columbia, Canada.

Protocol and service selection

Paging carriers face many choices regarding which particular NPCS voice and data services to offer and the specific technology to operate them. These choices are driven by the market and by

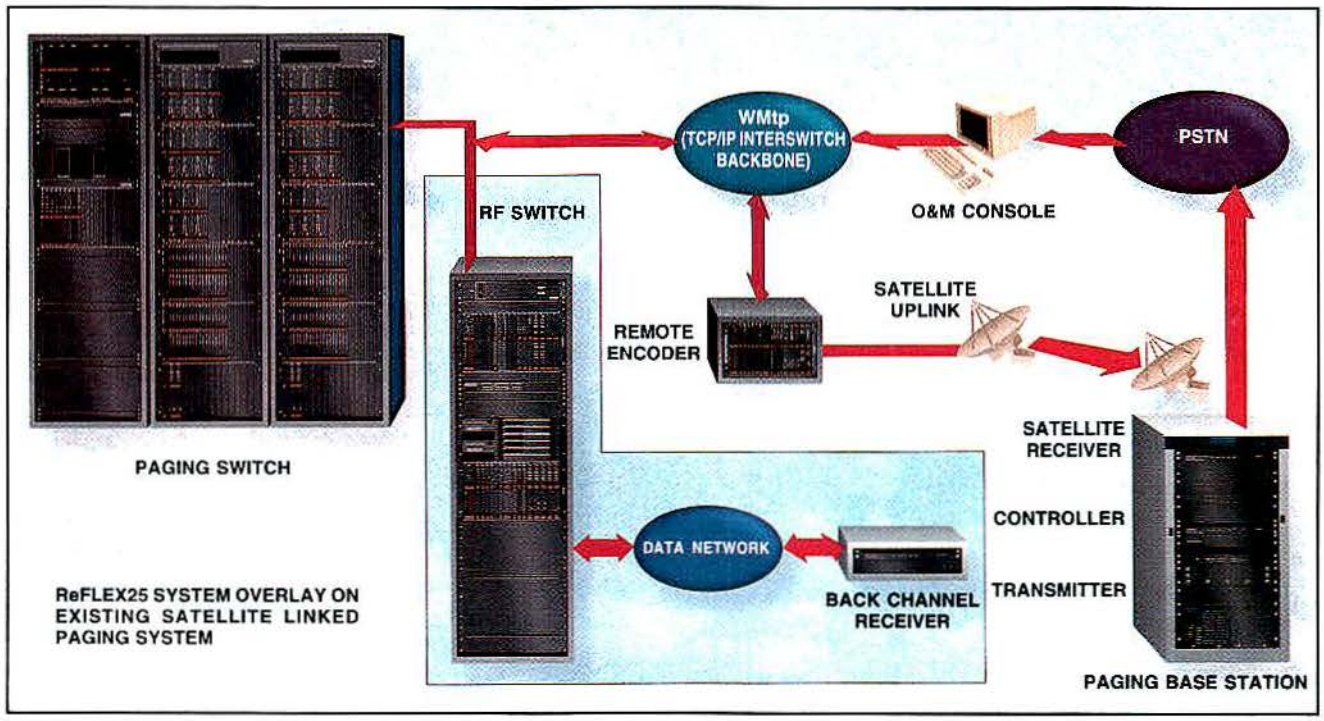
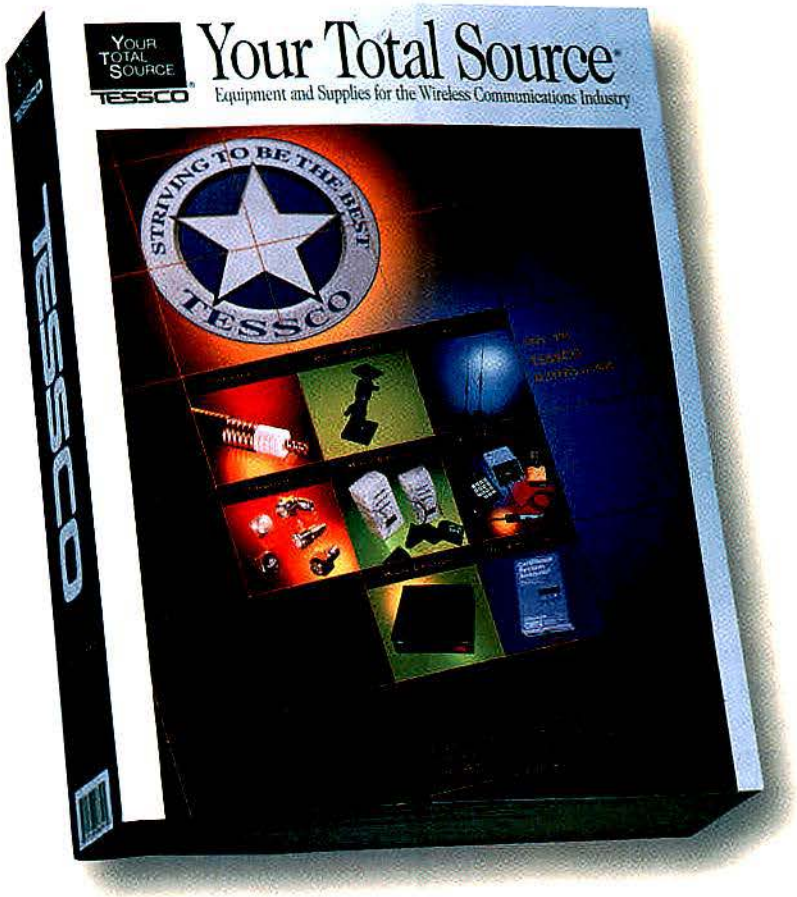


Figure 1. In this ReFlex 25 system, the paging switch, distribution system and transmitter infrastructure are the same as that of a Flex system. The only components that differ are the RF switch and the receivers.

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the cost and complexity of the necessary infrastructure. Among the protocol options and services available, Motorola's ReFlex 25 offers the easiest migration path.

Voice

Marketed as a wireless answering machine, PageNet's VoiceNow is a voice application that uses the InFlexion paging protocol. The RF system design for InFlexion is cellular as opposed to the traditional simulcast design used with Flex and ReFlex protocols. Because InFlexion requires a completely new RF infrastructure, migration from Flex to InFlexion is impractical.

Instead, to take advantage of the opportunity to sell voice paging service, smaller carriers easily can resell a large carrier's voice service by connecting with the larger carrier's RF network. This connection can be made with the Glenayre-licensed networking standard, the *wireless messaging transfer protocol* (WMtp). Developed for NPCS and one-way paging, WMtp is based on TCP/IP (transmission control protocol/Internet protocol), and it supports the transfer of NPCS (including InFlexion voice) messages between paging switches. Any link media that supports TCP/IP, such as *frame relay* or *integrated services digital network* (ISDN), can be used. WMtp surpasses the current one-way protocol, TNPP (Telocator network paging protocol), by increasing capacity, simplifying network management and improving congestion control.

Data

Many carriers prefer a data application to voice because it appeals to the market they serve. NPCS protocols that support data include ReFlex 25, ReFlex 50, pACT and InFlexion. With the exception of ReFlex 25, these encoding formats have relatively complex modulation schemes to support higher data rates on the forward channel. Because ReFlex 25 can operate with conventional FM transmitters, it is best suited for easy migration from one-way Flex paging.

One-way alphanumeric paging is hitting its stride in the North American marketplace. Some of the impressive services now available include wireless E-mail, World Wide Web (Internet connectivity) and information services (e.g., stock reports, sports scores and weather reports). With Flex alpha pagers now available, carriers that are upgrading their systems to Flex to add capacity will find ReFlex 25's features to be an excellent extension of one-way alpha paging.

From a cost perspective, ReFlex 25 offers frequency reuse that greatly increases system capacity. New services that will be possible include guaranteed delivery and short responses. In addition, the response channel can add interesting enhancements to the one-way services (wireless E-mail and information services) mentioned above. For example, mobile customers could subscribe to local weather or traffic reports while they are on the road.

ReFlex 25 can be described as a Flex forward channel coupled with a response channel. Two-way capability is created by adding a receiver network to the Flex system. As with Flex, ReFlex 25 is a synchronous protocol that uses 6,400bps, 4-level FSK (frequency-shift keying) modulation, and it has a single carrier in a 25kHz channel. Figure 1 on page 20 shows a Reflex 25 system. The paging switch, distribution system and transmitter infrastructure are the same as that of a Flex system. The only



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components that differ are the RF switch and the receivers.

Example

America's largest private carrier, Westlink Paging of San Diego, has selected its migration solution in implementing NPCS and Flex technology. Westlink is a partner in Benbow PCS Ventures (June Walsh, president and majority owner), which holds licenses to a common NPCS channel in the West and Central regions.

Driven by the demand for capacity and the advent of Flex alpha pagers, Westlink decided to upgrade its transmitter network to be compatible with Flex. Westlink purchased a Flex system that also can serve as the forward channel of a ReFlex 25 system. Westlink chose conventional FM transmitters with satellite distribution, as well as a high-speed control system capable of supporting both Flex and ReFlex. Able to switch among POCSAG, Flex and ReFlex traffic, the Glenayre-supplied transmitters will serve as the forward channel for Westlink's ReFlex 25 beta test and market trial in San Diego.

Rex Snyder, Westlink's vice president of technology, described Benbow's approach: "Although we have over 450,000 subscribers, we have chosen to minimize the risks of early NPCS deployment. We prefer to keep close to the technology and understand the benefits, market applications and costs thoroughly to deploy efficiently at the appropriate time. We are testing ReFlex 25, and we will be poised to implement quickly as devices become available. At the same time, we are evaluating the potential of other advanced NPCS protocols and planning long-term migration paths. We are excited by the opportunity to provide high-value services to more customers."

Smaller carriers ...can greatly reduce their investment by choosing technologies and services that leverage existing paging infrastructure.

Linear technology vs. FM

Linear transmitters are necessary to support several NPCS encoding formats such as InFlexion and ReFlex 50. The linear transmitters now offered by paging infrastructure suppliers also are capable of supporting one-way protocols such as Flex and POCSAG. This leads to the question, Why not purchase linear transmitters to satisfy present one-way requirements?

At first, linear technology seems to offer easy migration from one-way to more advanced protocols. However, carriers must carefully analyze their requirements and determine whether this new technology is a wise investment. Linear technology is more expensive than traditional FM transmitters. Carriers should invest in linear transmitters only if they plan to employ a protocol with a complex modulation scheme (such as InFlexion) or if they run multiple FSK carriers in a 50kHz channel.

Infrastructure checklist

The following list summarizes some important questions to consider when selecting a two-way system or purchasing new one-way infrastructure.

▶ *Transmitter*

☐ Will the transmitter control system support Flex and ReFlex?

☐ Will the transmitter support Flex and ReFlex frequency deviation?

☐ Can the transmitter's exciter switch efficiently between one-way and NPCS frequencies?

☐ Can the control system be upgraded to support linear transmitters?

▶ *Switch*

☐ Will the switch support the NPCS networking protocol WMtp?

☐ Can you resell other carriers' voice service?

☐ Will the switch support data applications?

☐ What upgrades are required for your billing system?

Entering the NPCS marketplace may at first seem like a costly venture. The paging industry's great expectations for NPCS are evidenced by the great investment that has been made so far. Smaller carriers, though, can greatly reduce their investment by choosing technologies and services that leverage existing paging infrastructure. By employing such a strategy, carriers can be competitive and take advantage of the new opportunities of NPCS.

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Tips for police cruiser installations

Pre-planning, care in running wire and cables, a master ground and proper antenna placement are keys to a successful installation. Good quality control is also an important element in preventing unnecessary callbacks.

By Donald E. Koehler

Major urban, with an increasingly large number of suburban and rural, public safety departments are equipping their patrol fleets with modern, powerful cruisers. If these vehicles come to the installer fresh from the dealer or supplier, a tremendous amount of work is in store for the technical staff. In addition to a light bar, siren horn(s), radios, antennas, wig-wag (headlight drivers) and corner strobe lights, the installer will also add many new police tools. These tools can range from speed radar to video camera and recorder system to Doppler direction-

Koehler is the owner of Communication Specialties, Anchorage, AK.

Video system installation tips

The advent of video systems in patrol cars has been a very positive addition for officer safety and DUI/DWI convictions. The Anchorage [police department] has installed these systems into special traffic patrol cars, which are used to enforce the very tough Alaskan drunk driving laws. Let's look at a typical installation.

The key components of this system are a low-light video camera, trunk-mount recorder, interior video monitor and control panel, and an officer-worn wireless mic. As shown in this set of photos, the wireless mic requires a trunk-deck-mount external antenna due to the low transmitter power. What should the installer know before starting an installation?

First, the video monitor mounts on a modified cellular mount next to the main radio console. All wiring—power, control, video—that leads to the trunk unit is routed through the overhead. This permits the rear seat to be used to transport prisoners without worry about damage to wires run under the carpet or compromise to the shield divider.

The control panel mounts on the roofline out of the driver's line of vision, while allowing access to the roof frame for a solid mount. The camera mounts to the rear-view mirror post. This location provides a wide field of view with minimal obstruction of driver vision. Just above the mount, the camera and control panel cables enter the headliner. While fishing through the overhead, why not run the antenna cable at the same time? This will keep the floorboards clear of all cables.

The trunk-mounted recorder box is large enough to take up a fair amount of space, but the trunk provides shock and temperature protection. The box is equipped with a padlock to provide protection and legal control if required. The officer can change tapes without help, using commercially available tapes. The deck-mounted antenna finishes the system.

The trunk-mounted antenna permits maximum gain for the low-power wireless mic. The officer can turn the mic on as needed. This audio track on the video tape makes for convincing evidence at DUI/DWI trials. The entire system is controlled by the driver with the control panel located just above the rear-view mirror. All in all, this video system is a powerful tool in the effort to make the streets safer for all.



An overhead-mounted control panel is easy for the driver to see and to operate.



The video monitor is easy for the driver to see and to adjust.



A low-light camera captures the action for later use in court.



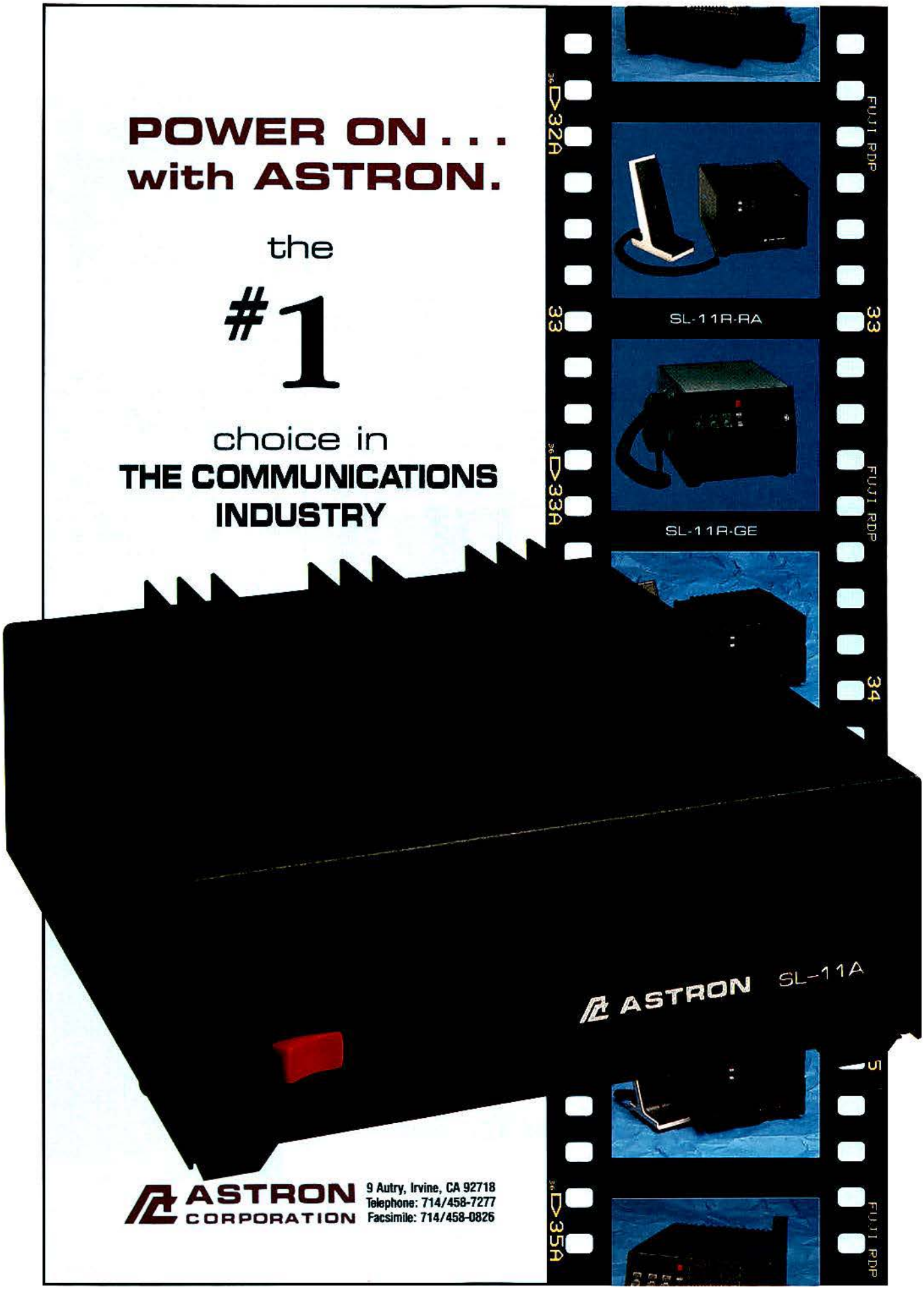
The low-power wireless mic requires the use of a deck-mounted antenna. Note the mic on Officer Stillwell's jacket.

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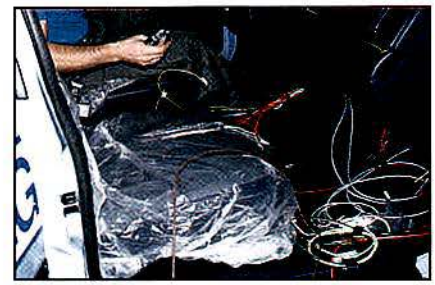


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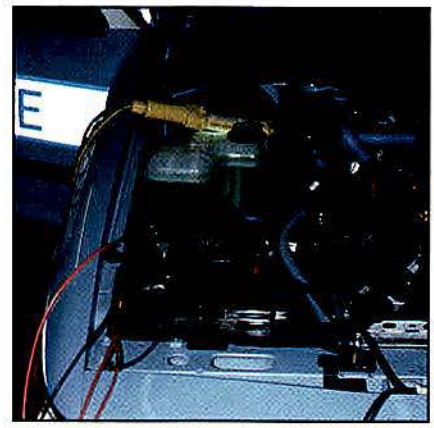
finding and tracking systems to computers giving officers a direct link to databases. As always, pre-planning is a key element to a successful installation. Let's begin with a new Ford Crown Victoria and look at what is required to turn it into a modern police tool.

The outside light bar, pusher bumper, corner strobe units and other structural items may best be installed by the garage or mechanic who will service the vehicle in the future, rather than your radio shop. The light bar wiring and controls can easily be installed by the radio shop in order to keep complete records—more on this later. Outside siren horns should be mounted at the same time. With that done, measure the space in and under the dash available for equipment. Keep in mind that you must allow an interior "safe zone" for air bag deployment. Ensure installed equipment does not interfere. If in doubt, check with the dealer or expert service personnel familiar with the size of inflated air bags. Don't forget to allow space behind or near radio mounts for wiring bundles under and through the dash and firewall. With the smaller size of new vehicles and the large amount of police equipment normally found today, you will almost always be forced to use a console mount to hold the multiple control heads, radios and light controls. Remaining controls for the VCR system are mounted in the overhead, safely out of the way.



After the mounts are installed, it is time to pull wiring for the cruiser's power and signaling systems.

Once you have measured and loosely fit the console, check the operator's preference for the stacking of equipment and control heads. Customer involvement in this early stage can eliminate potential problems and help to build a good working relationship. Now you have a good grip on where the wiring will have to run. As an aside, most installers find they must use the trunk area to mount R/T modules, siren amps, auxiliary equipment or other units. Given the amount of gear carried in the trunk by most safety officers, care must be used in placement of communication and signaling equipment. A plate rigidly mounted on the side of the trunk will help, or consider using the underside of the rear deck. The technicians here at



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the Municipality of Anchorage, AK, radio shop have indicated to me that the underside of the deck works well for them and provides good protection for the equipment. Given the extreme cold temperatures found here, however, radios are mounted inside. In a warmer climate, like the desert Southwest, consider problems related to heat-loading in trunk-mounted equipment.

Set the mount or console aside and pull the wire and cable. Use care to protect the wires or cabling run under the floor. Feeding antenna cable of the 'A' post (windshield support post) and to the antenna is easy—a smooth fish tape will help avoid damage to the headliner. Carpet can be removed temporarily, if necessary. Before you drill through the firewall, double check both sides! I have embarrassed myself by drilling into odd things behind the firewall. Some vehicles have grommeted holes that



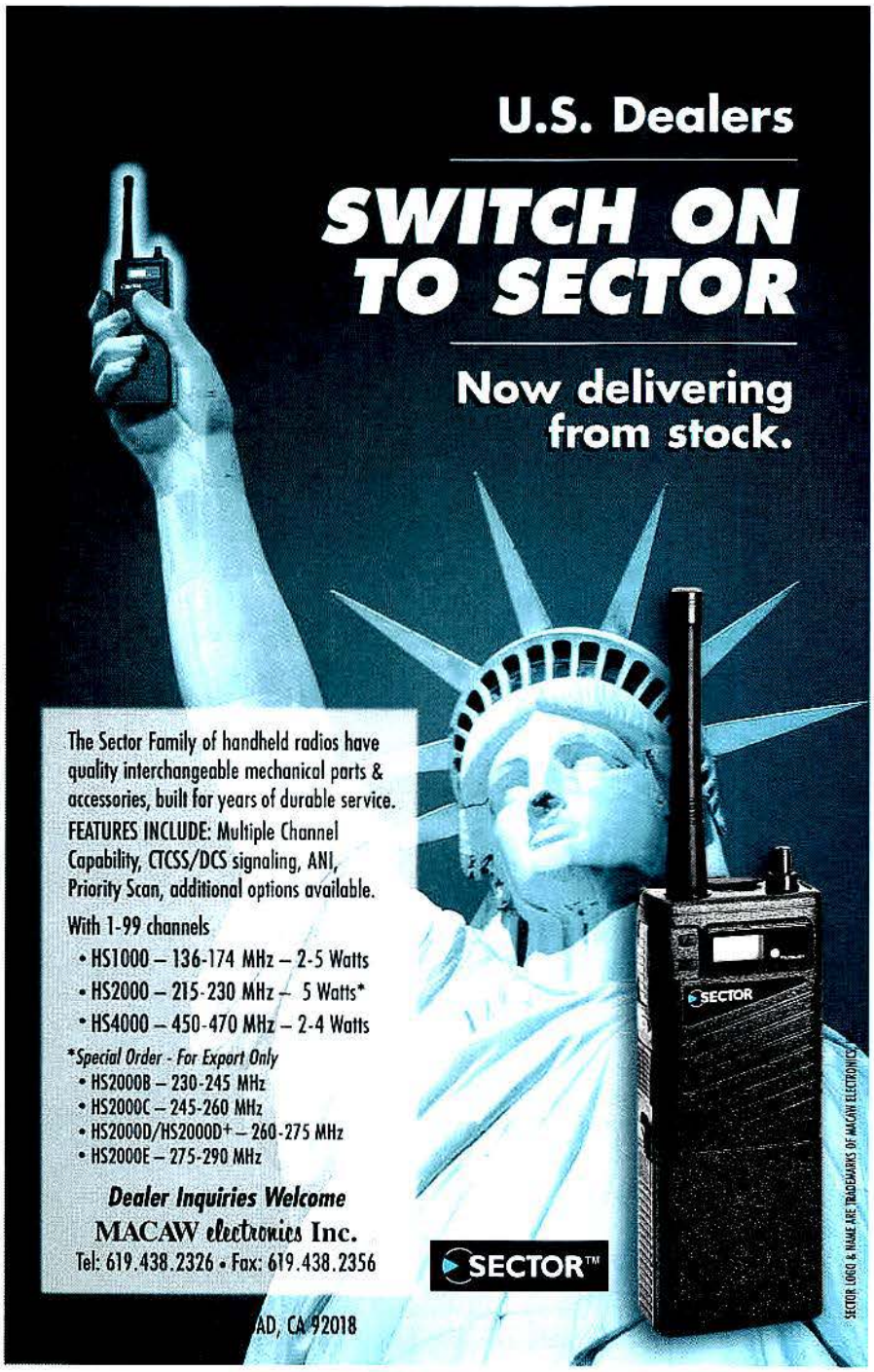
Check with the user or operator to set the 'stack' of equipment in the console. For large fleets, the use of a stack may not be consistent with standardization.

may be suitable if enlarged. Always protect the wires with a grommet or other chafe-reducer.

A master ground will go a long way toward stopping interference before it starts. Running a tie wire between the battery, body, frame and the equipment console, all tied to a common point, is best. Use the correct gauge of wire, based on equipment current draw, and avoid splices. Place the ground point where you can easily check and service it. A master power (positive battery) buss may help in the installation. A master switch or fuse near the battery is essential for safety. You should always consider a low-voltage cutout or magnetic relay to prevent battery drainage while the vehicle is off or unattended. Finally, make notes or a line drawing of the installation wiring; nobody lives forever, and sometimes you do go on vacation, so give your coworkers a break and document your work.

Now that the wiring is in, permanently mount the console and radios. Once all equipment is mounted, check that each system will power up as you connect it. This will simplify any troubleshooting, should any be necessary to bring the system on line. With that done, you can then finish the wiring by using tie wraps, looming or clips to secure everything. Marking or tagging the individual wires in the harness, indicating the unit supplied, will save time in the future, should problems arise. At this point, a copy of the wiring harness drawing or diagram and wire list/marking should be placed in the vehicle service file. This should include the type and size of fusing, and modifications such as 'wig-wag' headlights, switching for light bar and so on. Now back to the outside.

Antennas and related cable require some thought. Antennas should be placed



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The trunk may be used to carry large equipment. The upper deck offers mounting possibilities the installer should examine.

away from light bars, strobes or other obstructions that could distort or block the transmitted signal. Additionally, interactions between systems need to be considered. New video recorders found in public safety vehicles often use low-power "wireless" or radio mics. The recorder/receiver unit is mounted inside the trunk, in a sturdy, lockable "box." Radar units and in-vehicle repeaters are other examples of potential systems that could cause conflicts. For those installations where undercover work is anticipated, replacement automobile-style antennas or mag-mount DDRR-type antennas can be considered. If you mount antennas under the vehicle body, say a mag-mount DDRR, take care to attach the cable to avoid snags or chafe, which could cause damage.

Take the time to check the quality of your work when finished. Test each system and the total of installed systems before turning the vehicle over to the user. Always take the time to go over all the installed systems in a short "training" session with the operator. Even experienced public safety personnel may have questions that are best answered at the beginning rather than as a trouble callback. You could combine the final checkout with a training session to save time and effort.

Pre-planning, care in running wires and cables, a master ground and proper antenna placement are some of the keys to a successful installation. Proper documentation, operator training and systems testing are keys to prevention of unnecessary downtime and callbacks. Integration of new technology—video, radar or direction-finding systems, can be simplified with this system-based approach. Best of luck on your next install.

Acknowledgments:

To Gene Sole, manager; Edward Wise, David Dias and Jess McDonnell, technicians at the Municipality of Anchorage, AK, radio shop; and Officer Stillwell of the traffic unit. Thanks to all of these professionals for taking the time to answer questions and for photography.

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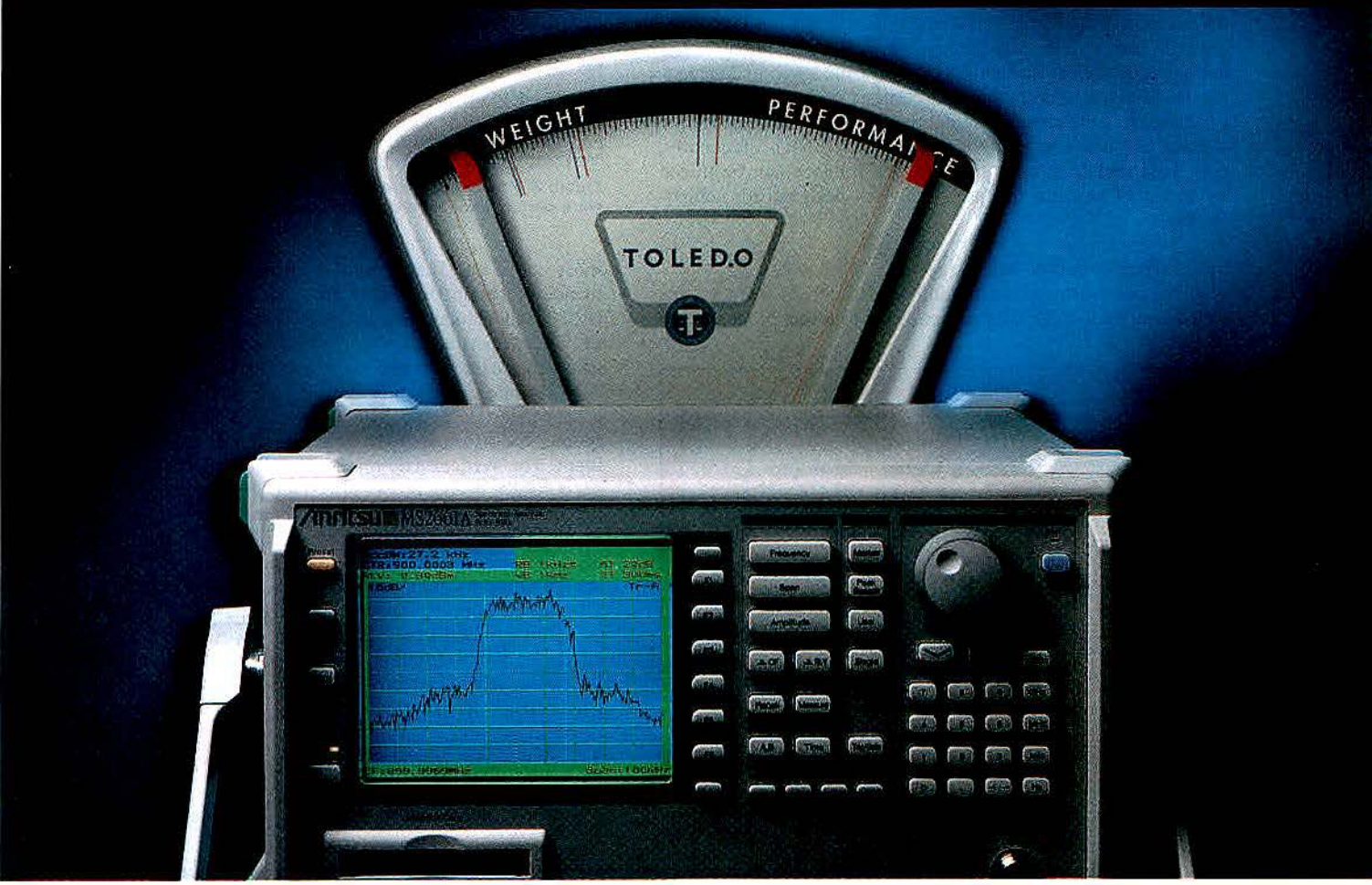
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How mobile radio fading affects RF data modems

Part 2—Vehicular modems must provide high throughput in RF fading environments. Basic design techniques and performance measurements aid development and evaluation of wireless systems.

By Barry L. Dorr

Some land mobile RF data modems just seem to work better than others. Often, a modem will work well when the vehicle is stationary, but behave poorly when the vehicle is in motion. Sometimes, the exact opposite is true. Sometimes a mobile data network consisting of 9,600bps or 19,200bps modems will have an inbound channel throughput of less than several kilobits per second (kbps). This article describes several key mobile RF data modem performance measurements. It then describes how well-engineered data modems achieve good performance in the land mobile environment.

The first article in this series (*November 1995*) showed that RF signal fading is a natural phenomenon that causes burst errors in land mobile data transmissions. Because fading limits the performance of land mobile RF data modems, understanding its behavior is important. In contrast to land mobile data systems, the performance limitation for modems intended for satellite use is a low *signal-to-noise ratio* (SNR). Frequently, poor land mobile RF data modem performance can be traced to the use of modems that are simply not designed for vehicular use.

System performance measures

There are many measures and specifications used to describe land mobile RF data modems, but two sets of curves are most important. The first curve specifies the decoding performance of the modem as a function of *received signal level* (RSL) and vehicular speed. The second curve specifies data throughput performance when a large number of modems are using the same inbound (mobile-to-base) frequency.

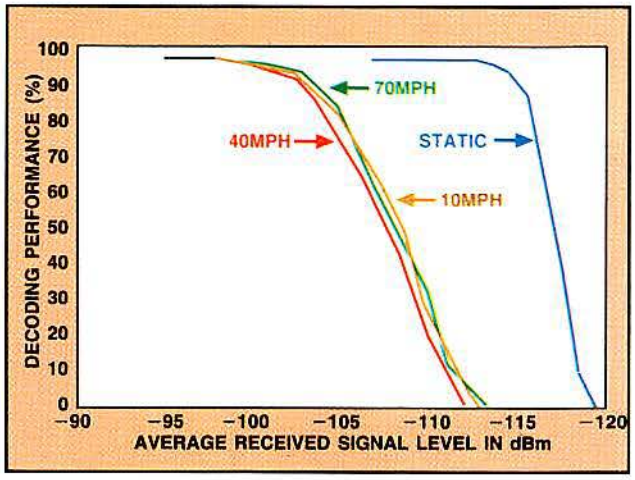


Figure 1. Static and faded decode performance for a vehicular modem.

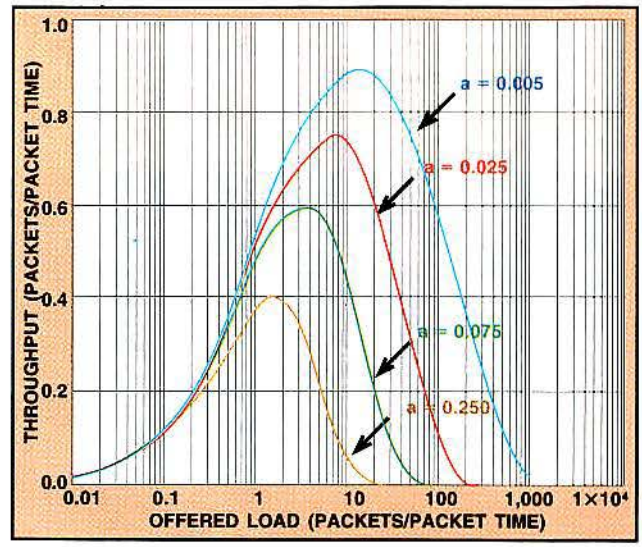


Figure 2. Inbound data throughput curves are used to determine network performance as a function of desired throughput.

▶ *Decode performance curves* — Figure 1 at the left shows a set of decode performance curves. The horizontal axis represents the average RSL measured at the receiver's antenna input. The vertical axis represents the percentage of messages successfully decoded. Because many modems allow for varying message lengths, these tests should be performed using a nominal length data packet. The static curve on the right shows decode performance in a non-fading environment. This curve can be generated using an RF service monitor, and it provides a useful baseline for the modem. The curves on the left show the decode performance in a fading environment. These three curves represent different vehicle speeds. Mobile fading simulators, available from various manufacturers, are used for faded performance measurement.

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Decode performance curves are normally used for system coverage calculations. Customer requirements provide the required message-decode probability. The minimum required mean signal level is then determined from the faded curves on the left. Next, this level is entered into the system link budget and converted to an estimated coverage area using computer coverage analysis. As a practical matter, the data from the static curve often are entered into the link budget, and an extended coverage area is determined. The extended coverage area shows the increased service area that is often available when vehicles are stationary.

▶ *Throughput curves* — Figure 2 on page 34 shows a set of calculated inbound data throughput curves. These curves show the amount of inbound data successfully decoded by the base station receiver and passed to the host computer. The curves shown are typical for a system using *digital sense multiple access* (DSMA) contention control. (See sidebar, page 38.) Throughput curves are commonly found in system documentation, but frequently are misunderstood. An example of the usefulness of the throughput curves is shown in Figure 3A at the right. The user's peak throughput demand is compared to the maximum throughput of the system. Figure 3B on page 40 shows the success probability of a signal transmission as a function of the operating point. Figure 3C on page 40 shows decode success probability as a function of the number of retries.

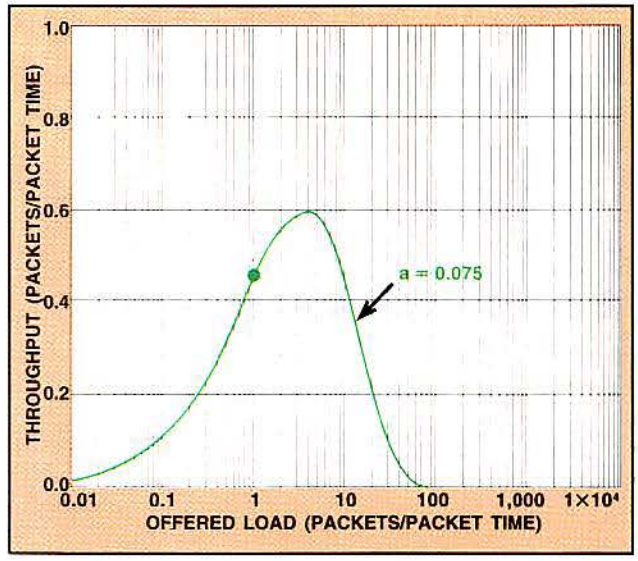


Figure 3A. Throughput for 200msec packets. The contention window is 15msec. A practical operating point for this system provides 46% throughput. The peak throughput for this system is 60%.

Four design techniques for vehicular modems

Error control refers to the process of adding redundant bits to data packets so that transmission errors either are detected or are corrected by the receiving modem. An important system design consideration is the balance of error detection and correction. Consider a system with only the ability to detect and reject corrupted packets. The data throughput of such a system would be quite low because the RF fading process nearly

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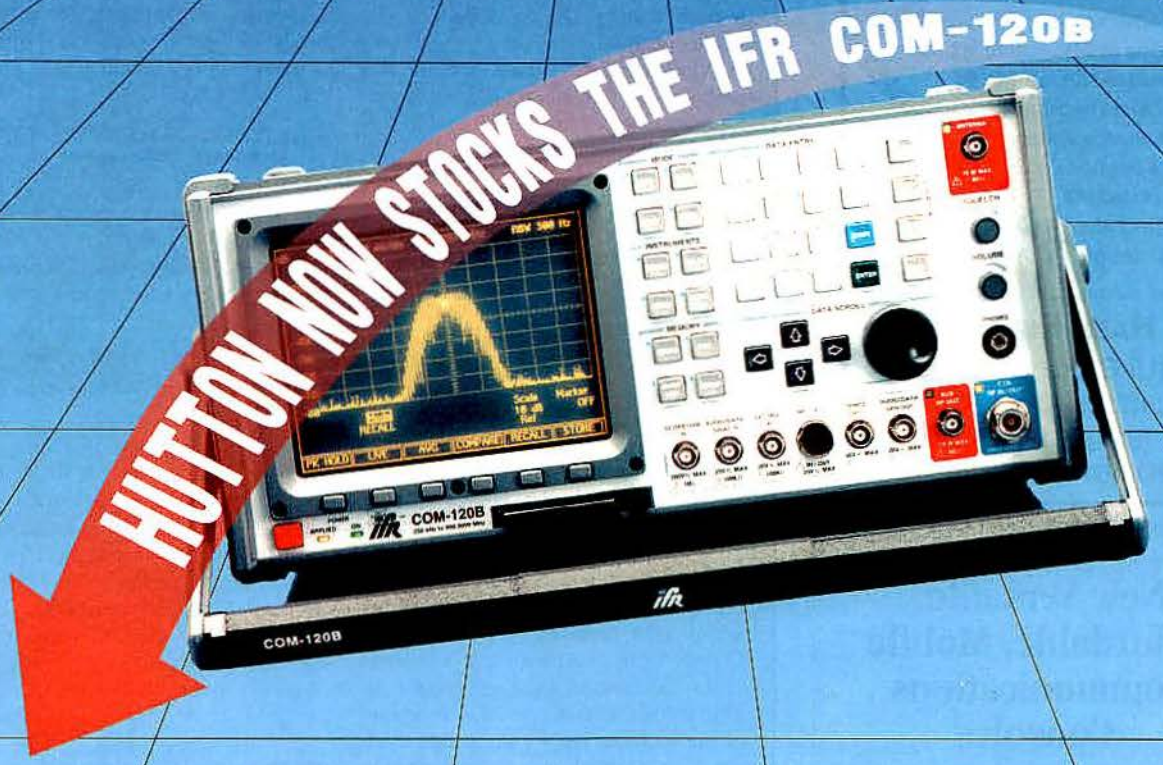
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Description and practical application of DSMA

Digital sense multiple access (DSMA) is a channel access technique that provides high data throughput when a large number of mobile units access a single base station receiver. Most commercially available high-speed mobile data packet networks use some form of DSMA for inbound contention control. Basic DSMA is described below.

When DSMA is used, special bits embedded in the outbound (base-to-mobile) channel inform all mobiles of the status (busy or clear) of the inbound channel. Collisions are reduced because mobiles do not transmit when they are aware that the inbound channel is busy. If a vehicle wishes to transmit and detects that the channel is busy, it waits a random time called the *backoff delay* before checking again.

DSMA fits well into mobile data systems for several reasons. First, it requires separate inbound and outbound radio frequencies, which is a typical channel assignment. Second, the base radio must be capable of transmitting and receiving simultaneously, which is common for base radios. Third, the base radio must be capable of continuous transmission, which is a common option. Finally, DSMA works well with typical mobile radios because it does not require simultaneous transmission and reception at the mobile. The result is that existing voice systems may be converted to data networks by adding modems and leaving the basic infrastructure intact.

Inbound data throughput is strongly dependent on a characteristic called the *contention window*. This is defined as the amount of time from when a mobile unit commits to transmitting to the time when the rest of the mobiles on the channel know the system is busy. A long contention window decreases data throughput because if one mobile has begun a transmission, and the rest of the mobiles do not know that the inbound channel is being used, collisions can result. The two main constituents of the contention window are the mobile transmit turn-on time and the base modem acquisition time.

The curves shown in Figures 2 and 3 are typical for *random access* networks such as DSMA. The vertical axis of Figure 2 represents throughput. The horizontal axis represents offered load. The offered load is the average arrival rate of both new and retransmitted packets to the RF network.[1] These curves can be confusing because the curve always is normalized to packets-per-packet time. Referring to Figure 3A, the operating point is 0.46 packets per packet time. De-normalize as shown below to express throughput in packets per second.

$$0.46\frac{\text{packets}}{\text{packet time}}\times\frac{1\text{ packet time}}{0.200\text{ seconds}}=2.3\frac{\text{packets}}{\text{second}}$$

The normalized contention window is commonly referred to as "a." In Figure 3A, the contention window of 15msec results in a value of

$$a=0.015\text{ seconds}\times\frac{1\text{ packet time}}{0.200\text{ seconds}}=0.075$$

A useful property of a throughput curve is that the probability of successful transmission is easily calculated as the vertical axis value divided by the horizontal axis value. More specifically, this is the probability of a successful inbound transmission given that the mobile checked to see whether the channel was busy. Referring to the operating point on Figure 3A,

$$\text{success probability}=\frac{0.46}{1.0}=46\%$$

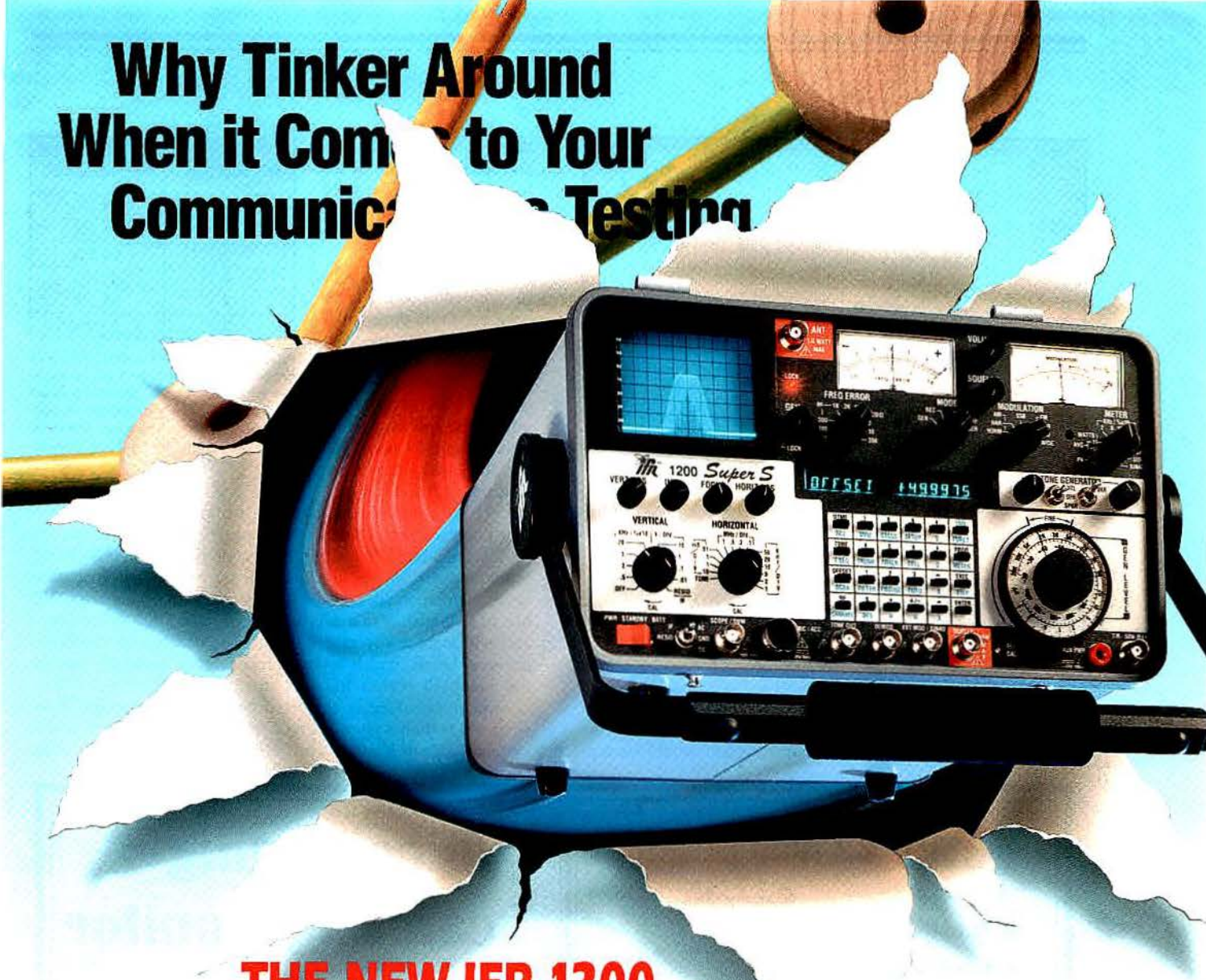
Success probability vs. offered load is shown in Figure 3B.

To effectively use DSMA, practical performance measures must be extracted from the throughput curve. One measure is the probability of success within a fixed number of retries. If the average backoff time for a system is one second, then Figure 3C shows a 97.6% probability that a message will be transmitted successfully within five seconds.

Reference

1. Kleinrock, L., and F.A. Tobagi, "Packet Switching in Radio Channels: Part 1—Carrier Sense Multiple Access Modes and Their Throughput-Delay Characteristics," *IEEE Transactions on Communications*, December 1975.

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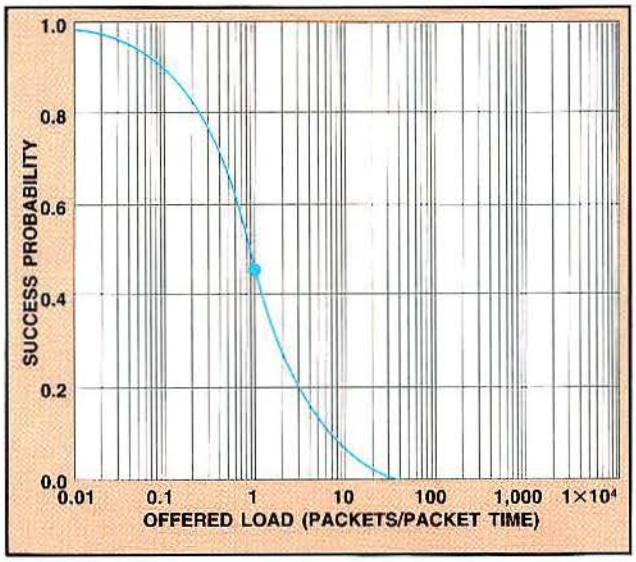


Figure 3B. As the required throughput for a DSMA system is increased, the transmission success probability decreases, resulting in more retries. Balancing throughput and delay yields operating points such as the one shown in Figure 3A.

always guarantees errors. Next, consider a system that would attempt to correct every packet received. When badly corrupted packets would be received, this system would attempt correction and would pass corrupted messages to the user. A properly designed system optimizes the balance for maximum data throughput.

NUMBER OF RETRIES	PROBABILITY OF SUCCESS
0	46.3%
1	71.2%
2	84.5%
3	91.7%
4	95.5%
5	97.6%

Figure 3C. Transmission success probability as a function of the number of retries at the operating point of Figure 3A. The probability of successfully transmitting an inbound message within five retries (six attempts) is 97.6%.

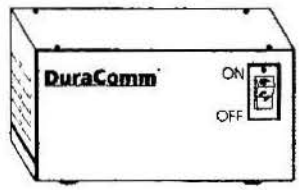
A simple example of error correction would be to send messages three times and to vote at the receiver, as shown in Figure 4A on page 42. The code shown in Figure 4A is conceptually simple, but two weaknesses limit its use. First the 200% redundancy significantly affects throughput. The second weakness is that two strategically placed errors could cause an undetected error.

A practical and frequently used code is the (63,45,9) Reed-Solomon code shown in Figure 4B on page 42. It is used in several commercially available systems. This code adds 108 bits of redundancy to a 270-bit data payload (40% redundancy) and will correct any nine bit errors. In addition, if the errors arrive in bursts, which is the typical case for a mobile channel, the code will correct for even more errors.

Data interleaving is explained best with an example. Consider a 9,600bps system using a 900MHz RF carrier. For this system, fades of greater than 15dB below the mean RSL cause

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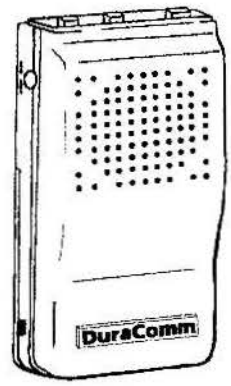


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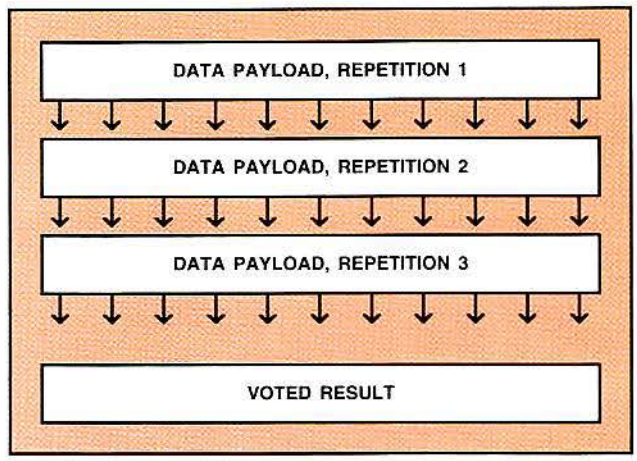


Figure 4A. The classical bit-voting code appends 200% redundancy to the data payload. One bit error always will be corrected.

the modem to take errors. At a vehicular speed of 45mph, the expected rate of fades below 15dB is 24.1Hz, and the typical duration of the portion of the fade below 15dB is 1.2msec or 12 bits.[1] If the data were sent in continuous, sequential blocks of 60 bits as shown in Figure 5A on page 44, the amount of redundancy required for successful transmission in this environment would be 66%. If the interleaver shown in Figure 5B on page 44 were used, the required amount of redundancy drops to 15.4%.

Interleaving takes advantage of the fact that in a fading environment, the *average* error rate is low. The interleaver *decorrelates* the burst errors so that the receiver's error decoder is presented with the average error rate instead of the higher burst error rate. The result of using the interleaver is that less redundancy is required for a given performance level.

Well-designed modems use a combination of error correction, error detection and interleaving. Note that the curves on the left side of Figure 1 are close together or nearly independent of the vehicle speed. This is the result of an error control strategy properly designed for vehicular use. If the faded curves are spread out horizontally, i.e., if the decoding performance varies with vehicular speed, the error control strategy is incorrect. This commonly happens when satellite or telephone line modems are used for vehicular applications.

Data compression is a technique that allows the modem to take advantage of the inherent redundancy of most data messages or graphic images. The basic idea is simple. Frequently transmitted characters should be converted to extremely minimal channel uses. Infrequently used characters should be represented using longer channel uses. A good, though not optimal, example is Morse code. This code represents the most commonly used letter in English, the letter "e," by a single dot. Conversely, the least frequently used letter, "z," is represented by the longer channel use of two dashes and two dots.

To understand the achievable performance of data compression techniques, it is useful to understand two basic

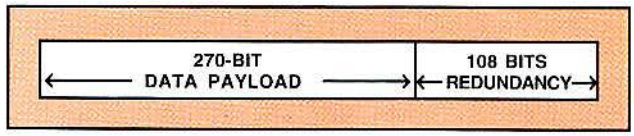


Figure 4B. This (63,45,9) Reed-Solomon code appends 40% redundancy to the data payload. Any nine errors always will be corrected.

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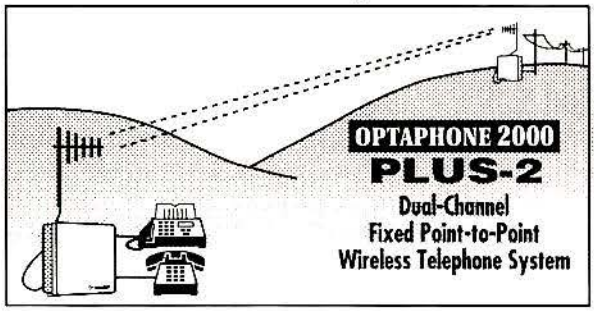
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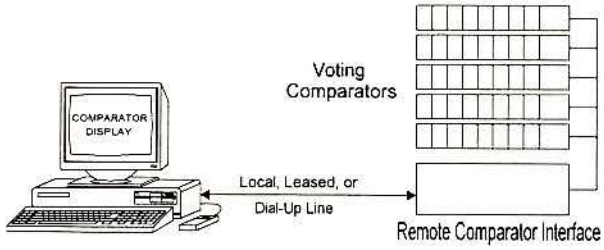
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1	2	DATA PAYLOAD, BLOCK 1	REDUNDANCY 1	59
60	61	DATA PAYLOAD, BLOCK 2	REDUNDANCY 2	119
120	121	DATA PAYLOAD, BLOCK 3	REDUNDANCY 3	179
180	181	DATA PAYLOAD, BLOCK 4	REDUNDANCY 4	239

Figure 5A. These data blocks are sent sequentially. The bit marked 1 is sent first, followed by 2, etc. Strong codes are required because burst errors often affect only one block.

distinctions. First, data compression techniques are either *lossless* or *lossy*. Second, they are either *adaptive* or *non-adaptive*. These properties are independent of one another, as shown in Figure 6 on page 46.

A lossless data compression scheme compresses source data so that the decompressed data match the source exactly. When text or transactional messages are compressed, lossless methods generally are required. Lossy data compression techniques do not pass all of the source information. Instead, they transmit only the data that are most important for the application. Lossy data compression is extremely useful for image transmission because the compression performance is high, and the losses are nearly undetectable.

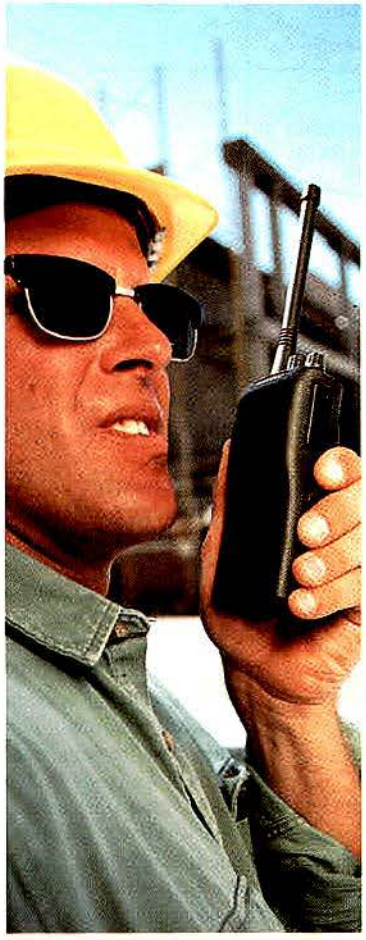
Non-adaptive techniques compress data according to a fixed rule. This works well if the data compression rule matches the statistics of the data being transmitted. For example, the Morse code matches English text. In a hypothetical language where "z" would be the most common letter and "e" the least common, the Morse code would yield a much lower throughput. Straightforward techniques can be used to generate a unique, non-adaptive compression code (a *Huffman* code) for almost any system requirement.

Adaptive techniques continually analyze the incoming data and modify the compression rule as required. The performance of these techniques is somewhat independent of the statistics of the data because the compressor adapts itself to them. For example, if an officer were to type an accident report with frequent uses of the word "vehicle," the compression algorithm would detect this and would represent "vehicle" with a

1	5	DATA PAYLOAD, BLOCK 1	REDUNDANCY 1	236
2	6	DATA PAYLOAD, BLOCK 2	REDUNDANCY 2	237
3	7	DATA PAYLOAD, BLOCK 3	REDUNDANCY 3	238
4	8	DATA PAYLOAD, BLOCK 4	REDUNDANCY 4	239

Figure 5B. In the interleaver arrangement shown above, bits are shuffled in time. The numbers show the transmit order. Burst errors affect multiple blocks, thereby reducing coding requirements.

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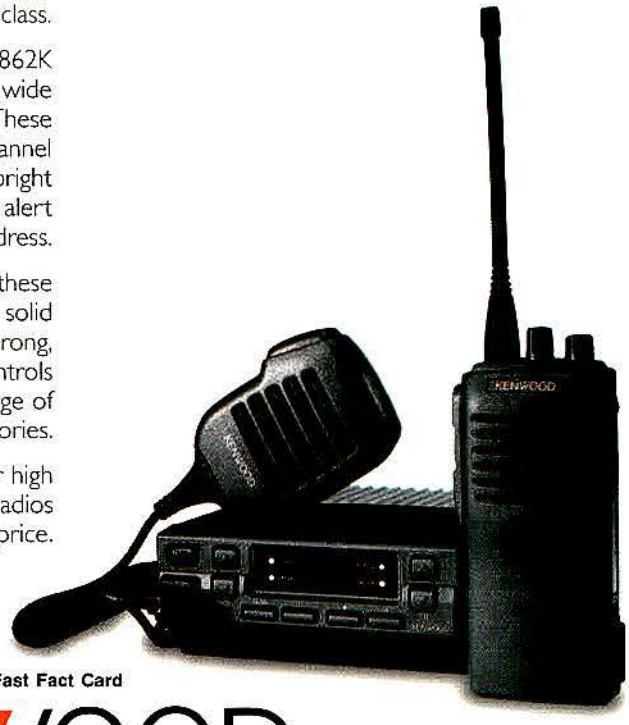
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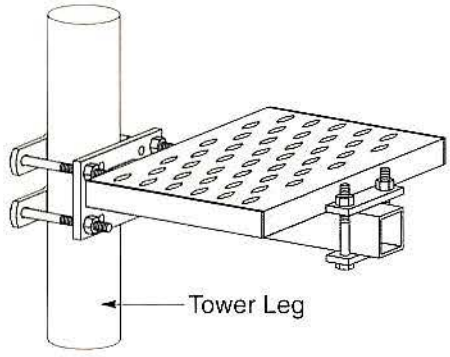
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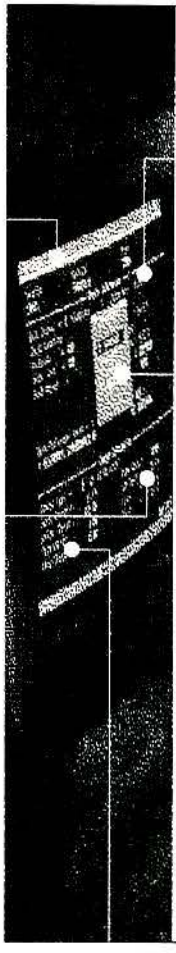


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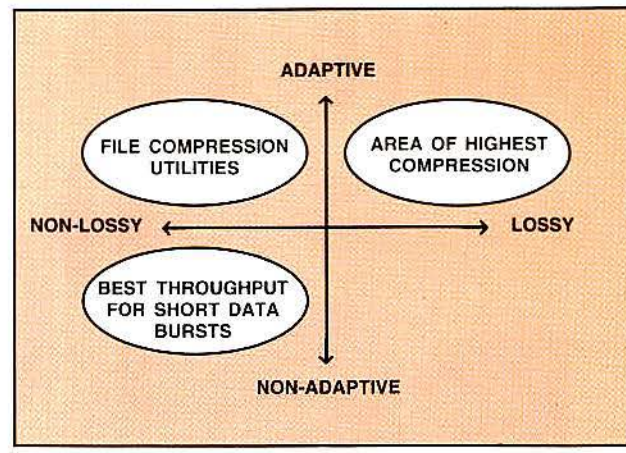


Figure 6. Data compression strategies can be mapped as points on a plane. Lossiness and adaptability are independent properties.

minimal channel use. The most common adaptive data compression is the *Lempel-Ziv* algorithm, which frequently is used for computer file compression utilities.

Both adaptive and non-adaptive techniques are useful in mobile data systems. Status or short text messages are best compressed using non-adaptive data compression; longer transmissions are best compressed adaptively. Conceptually, data compression strategies can be mapped as points on Figure 6.

Acquisition performance is a modem characteristic that directly affects system throughput. Acquisition time is the amount of time required for a receiving modem to determine that an incoming signal is present. In DSMA systems (see sidebar), the two largest constituents of the contention window are the mobile attack time and the base modem acquisition time. The acquisition curve in Figure 7 on page 48 shows the mean and standard deviation of acquisition time as a function of the receive signal level. This curve shows a good acquisition performance because the modem acquires reliably at quite low signal levels. A result of poor acquisition performance is that, although messages may be passed at low signal levels, the increase in the contention window significantly degrades data throughput.

Will it work?

Designing a modem to work in an RF-fading environment is an essential part of proper system design, but in itself does not ensure a successful system deployment. A modem should be flexible enough to satisfy varying system requirements. For example, if coverage over a large, sparsely populated geographic area is required, 600bps may be the correct rate. If the required coverage area is a small, densely populated area, then 19,200bps may work well. If the coverage area is large, and the number of frequencies is limited, the modem must be able to operate in a multisite, multifrequency system. The modem should also provide features that reduce installation and maintenance costs as well as features that maximize system reliability. Finally, developers of software applications should find the modem easy to use.

Conclusion

Understanding mobile data equipment can be an arduous task. Research articles continually describe exciting new techniques for wireless communications, and manufacturers sift through these research results, developing those which are practical and useful. Users and potential users of this equipment

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- Built-in CTCSS, DCS & Two Tone Sequential

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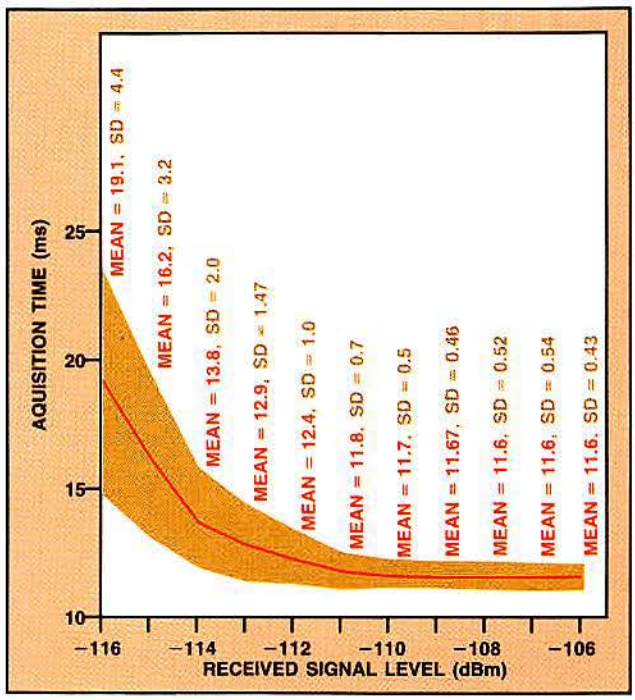


Figure 7. Mean and standard deviation (SD) of acquisition performance for a vehicular modem. Acquisiton time is shown as a function of the receive signal level. This modem shows good performance at low signal levels. *Figure courtesy of Coded Communications.*

are presented with tremendous amounts of information.

The intention of this article and Part 1 in the November 1995 issue has been to explain RF data modem performance in terms of some basic fundamentals. The first fundamental is the RF fading process, common to all wireless data systems, which was described in Part 1. Next, the basic performance measures, decode performance (sensitivity) and data throughput were described. Finally, four design techniques were described. Some or all of these techniques are used by most state-of-the-art RF data modems.

Reference

1. Reudink, D.O., "Properties of Mobile Radio Propagation Above 400MHz," *IEEE Transactions on Vehicular Technology*, November 1974.

RF modem series

Part 1—"How Mobile Radio Fading Affects Data Transmission," November 1995.

Part 2—"How Mobile Radio Fading Affects RF Data Modems," August 1996.

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Maintaining intermod level at communications sites

Evaluating the potential for intermodulation interference affecting the receiving frequency of the mobile units is important at sites where mobile (including portable) units might operate nearby.

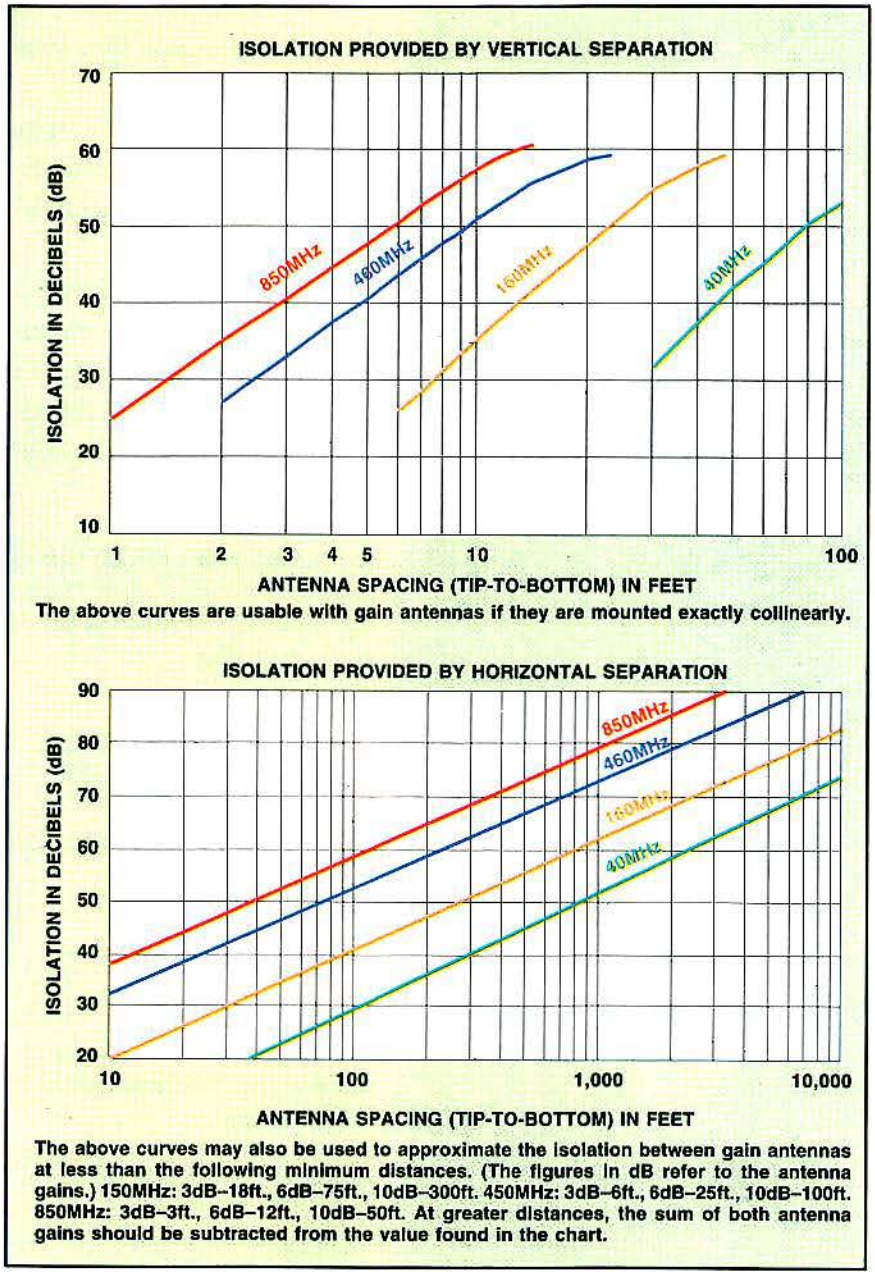


Figure 1. These antenna isolation curves are based on dipoles. Both reflect isolation values that could be expected when two antennas are separated as indicated. In actual installations, the obtainable values may vary somewhat, because of tower coupling or other reflective surfaces near the antenna. *(Courtesy of Celwave.)*

By David Parcigneau

Before deciding to install transmitting equipment for a new frequency at a heavily congested radio communications site, an electromagnetic compatibility (EMC) study should be conducted. Hardly any study is more complex. It takes into consideration *broadband transmitter noise, receiver desensitization* and *intermodulation interference* ("intermod").

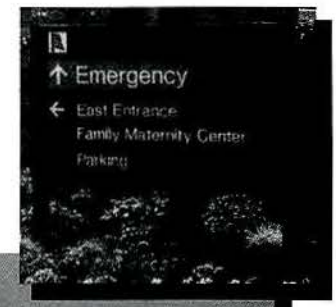
Once the proposed facility is shown to be compatible with respect to those three criteria, one more analysis, an *intermodulation level maintenance calculation*, might need to be performed. The evaluation is important at sites where mobile (including portable) units might operate nearby. It is less important at most mountaintop sites where users are not likely to come close. The analysis predicts the likelihood of intermod affecting the receiving frequency of the mobile units. Most site-related intermod studies only consider intermod that may affect the base station receivers at the site.

The analysis is simpler when the base station transmitters to be studied feed the same antenna through a combiner. It is more complex when the transmitters use separate antennas, perhaps on different towers. For example, you will have to use your own judgment whether to include in

Parcigneau is a radio inspector in Industry Canada's Radio Spectrum Management Montreal district office, Montreal, Quebec, Canada.

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If communication is vital to your operations, then you understand that equipment must be both versatile and easy-to-use. Even more importantly, it must be as reliable as the foundation under your building.



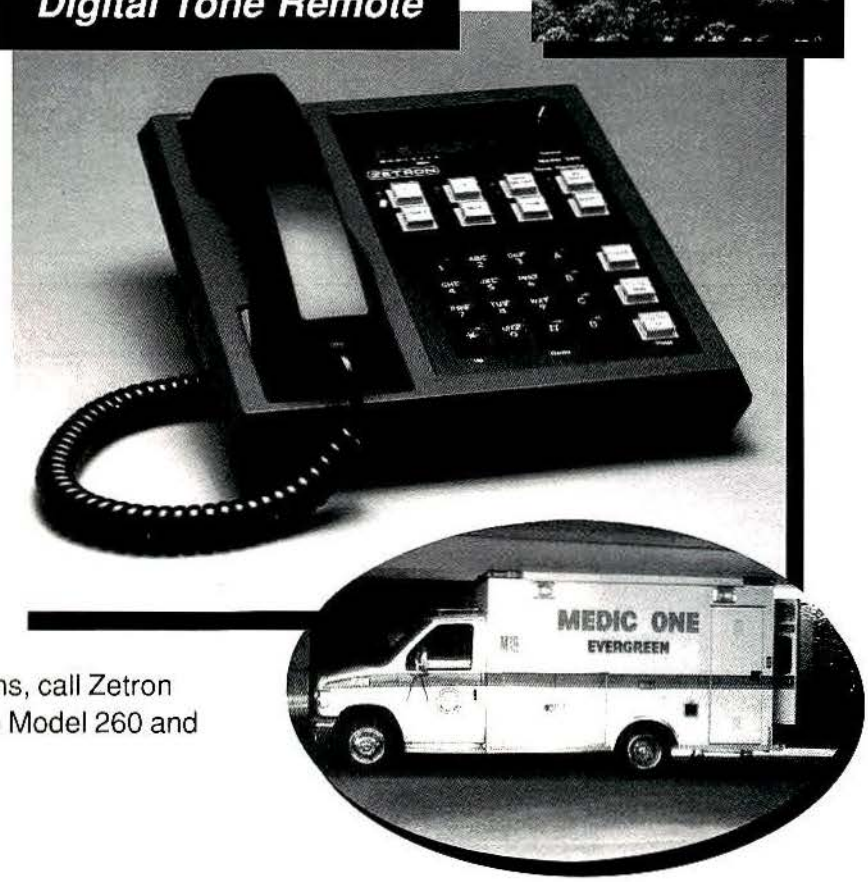
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Table 1—Attenuation values for vertically spaced antennas.

40MHz		160MHz		460MHz		860MHz	
SEP.M	ATT. (dB)	SEP.M	ATT. (dB)	SEP.M	ATT. (dB)	SEP.M	ATT. (dB)
0.0	0	0.0	0	0.00	0	0.00	0
10.0	31	1.0	23	0.60	28	0.30	25
10.3	32	1.3	24	0.65	29	0.32	26
10.5	33	1.6	25	0.70	30	0.34	27
10.8	34	1.8	26	0.75	31	0.36	28
11.0	35	1.9	27	1.00	32	0.38	29
11.3	36	2.0	28	1.05	33	0.40	30
11.6	37	2.1	29	1.10	34	0.45	31
12.0	38	2.2	30	1.12	35	0.47	32
13.0	39	2.4	31	1.14	36	0.50	33
14.0	40	2.5	32	1.16	37	0.55	34
15.0	41	2.7	33	1.20	38	0.60	35
16.0	42	2.8	34	1.30	39	0.65	36
17.0	43	3.0	35	1.50	40	0.70	37
17.5	44	3.3	36	1.60	41	0.75	38
18.0	45	3.6	37	1.70	42	0.80	39
19.0	46	3.8	38	1.80	43	0.90	40
20.0	47	4.0	39	2.00	44	1.00	41
21.0	48	4.2	40	2.10	45	1.05	42
22.0	49	4.4	41	2.25	46	1.10	43
23.7	50	4.5	42	2.40	47	1.20	44
25.7	51	4.8	43	2.50	48	1.25	45
27.0	52	5.0	44	2.60	49	1.30	46
		5.3	45	2.70	50	1.40	47
		5.5	46	3.00	51	1.50	48
		5.8	47	3.60	52	1.65	49
∞	52	6.0	48	3.70	53	1.80	50
		6.5	49	3.85	54	2.00	51
		7.0	50	4.00	55	2.10	52
		7.5	51	4.10	56	2.20	53
		8.0	52	4.35	57	2.35	54
		8.5	53	4.50	58	2.50	55
		9.0	54			2.60	56
		12.0	55			2.75	57
		12.5	56			3.00	58
		13.0	57	∞	58	3.50	59
		13.5	58			4.00	60
		14.0	59				
		15.0	60			∞	60
		∞	60				

the analysis a transmitter on the *nearest* frequency if it is situated at another *nearby* tower when another transmitter separated from the frequency under study by *only a few more kilohertz* is part of the *same* combining group with the proposed new transmitter. For transmitter intermodulation to be strong enough to cause a problem, the power levels involved must be strong and the transmitters must be close to one another, or both.

The path one signal must travel to enter another transmitter's output circuit and mix with the other transmitter's signal to produce intermod is complex and subject to much attenuation. Part of that attenuation is the path loss between the two transmitters' antennas.

Figure 1 on page 50 shows attenuation vs. distance for horizontal and vertical separation between antennas for different frequency bands. Table 1 at the left lists attenuation figures for vertically spaced antennas. Antenna gain affects attenuation, too, when the antennas involved are on the same horizontal plane.

Another component of the attenuation lies within internal transmitter filters and external filter cavities. Refer to manufacturer's specifications and duplex curves for these attenuation figures that apply to one transmitter at another transmitter's frequency.

Next, derive the conversion factor (CF) from the formula:

$$CF = 57\log(1.5 + \Delta F) - (9.9) - (9\log\Delta F)$$

where

ΔF = the difference in megahertz between each two transmitters' frequencies.

The possible levels of intermod that might be produced on the mobile unit receive frequency can be calculated using the path loss figure, the antenna gain figure (if applicable), the transmitter cavity and circuit filter attenuation figure and the conversion factor.

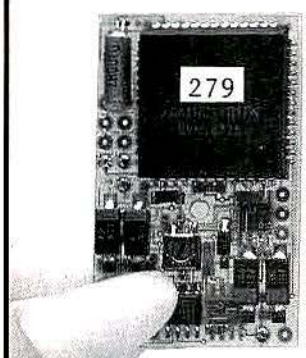
Here are examples of possible configurations to be evaluated and how to maintain an acceptable level of intermod in each case.

▶ *Example No. 1* — Transmitters on the same antenna.

The two transmitters are transmitter A (157.8MHz) and transmitter B (160.6MHz). Transmitter A has 18dBW (63W) output and a bandpass filter with a 1.5dB insertion loss. Transmitter B's feedline loss is 3dB, its bandpass filter has a 1.5dB insertion loss and its antenna gain is 7dB.

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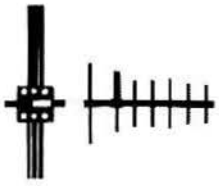
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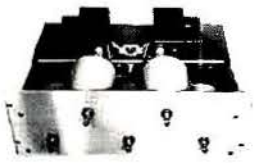
TS4680, also known as Cross Band Coupler. born 2-10-86; size 6.6 x 1.5 x 0"; 1 lb; hvy const; 400 watts; blue finish; tower mountable. Wanted by tower operators for multiple transmissions of 450-860 equipment.



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TC860, also known as Cellco Ceramic Trunking Combiner. born 5-25-91; size 7x19x14"; 36 lbs; rugged bld; 125 watts, alum finish. Wanted by SMR operators who want only the best.



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ANT450D3, also known as Dipole Array Antenna. born 9-14-58; known associates: other antennas in other freq bands and gain. hvy bld; blk TXYLAN coated. Known to violently resist corrosive gases, ultraviolet radiation, salt spray and acid rain. Wanted by tower operators with the worst possible problems.



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Model 44AP, also known as the Broadband RF Wattmeter. born 6-11-78; weight 4 lbs; rugged bld; 500 watts; gray comp; operates alone, no known associates; distinguishing marks: leather band on top, sample port right side. No known enemies, has been spotted worldwide.

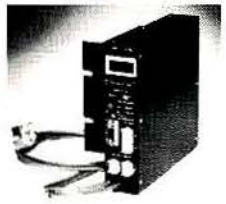


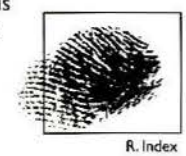


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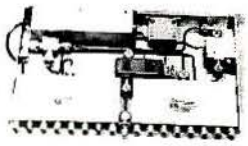




R. Index

Industry Top Ten Product

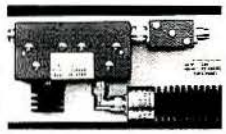
TWR816-860-1RTT, also known as Compact Receiver Panel. born 8-14-93; exceptional small build, likes to associate with multiple frequencies. Quiet 2.5 dB noise; modular; has been known to redundantly switch to 2nd channel if injured; likes living in harsh locations. Wanted for resisting interfering signals.



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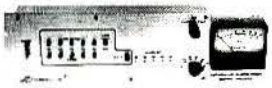


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PM5C1S, also known as Automatic Alarm Panel. born 2-23-81; brushed alum; 1.4 lbs; 19"x3.5"; Known associates: likes to snitch on bad trans & ant; needs to be placed inline; violently resists high VSWR; likes power. Do not approach, will call you.



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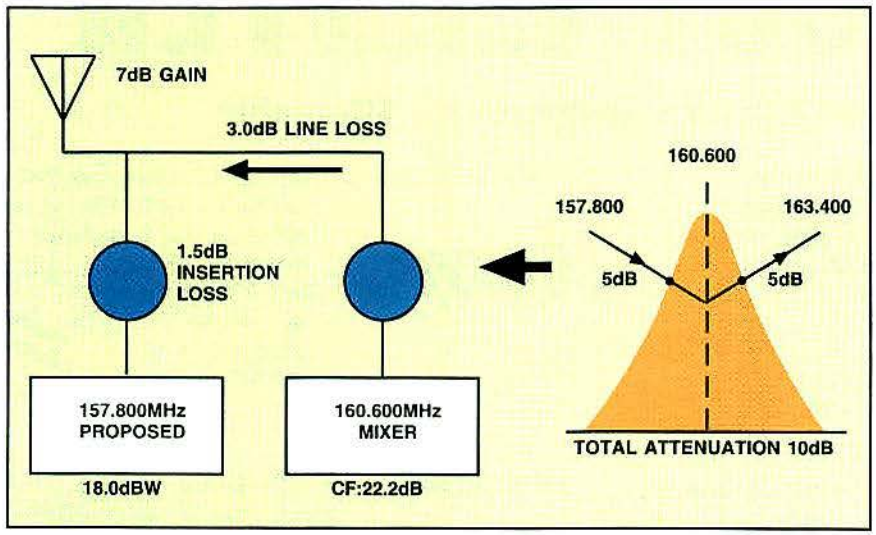


Figure 2. The signal path used in Example No. 1.

$$CF = 57\log(1.5 + \Delta F) - (9.9) - (9\log\Delta F)$$

$$= 57\log[1.5 + (160.6\text{MHz} - 157.8\text{MHz})] - 9.9 - 9\log(160.6\text{MHz} - 157.8\text{MHz})$$

$$= 57\log(1.5 + 2.8) - 9.9 - 9\log 2.8$$

$$= 22.2\text{dB}$$

The transmitter intermod level (TIL) then is calculated as follows:

$$TIL = P_{TX} - (IL_{TX} + 2FL_M + CF + LL) + AG_{TX}$$

where

P_{TX} = transmitter A power output
IL_{TX} = filter insertion loss at transmitter A
FL_M = filter loss of the mixer (transmitter B) at transmitter A's frequency. Refer to manufacturer's specifications to evaluate attenuation at desired frequency offset.
CF = conversion factor
LL = transmitter B's feedline loss
AG_{TX} = transmitter B's antenna gain

It is important to double the actual bandpass filter attenuation figure for this calculation, because the frequency response curve is symmetrical. The incoming signal of transmitter A must pass through transmitter B's filters, mix, and then pass again through the same filters at the intermod product frequency; thus, the outgoing intermod is subject to the same attenuation as the incoming signal from transmitter A. For other types of filters such as bandrejects, the only attenuation is at the tuned frequency. (See Figure 3 on page 56.)

Replace the variables in the TIL equation with values from the example, and calculate TIL as follows:

$$TIL = 18\text{dBW} - (1.5\text{dB} + 10\text{dB} + 22.2\text{dB} + 3\text{dB}) + 7\text{dB}$$

$$= -11.7\text{dBW}.$$

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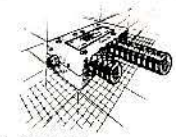
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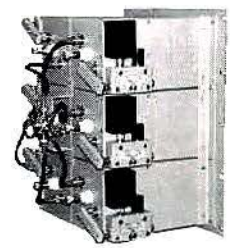
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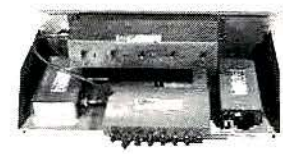
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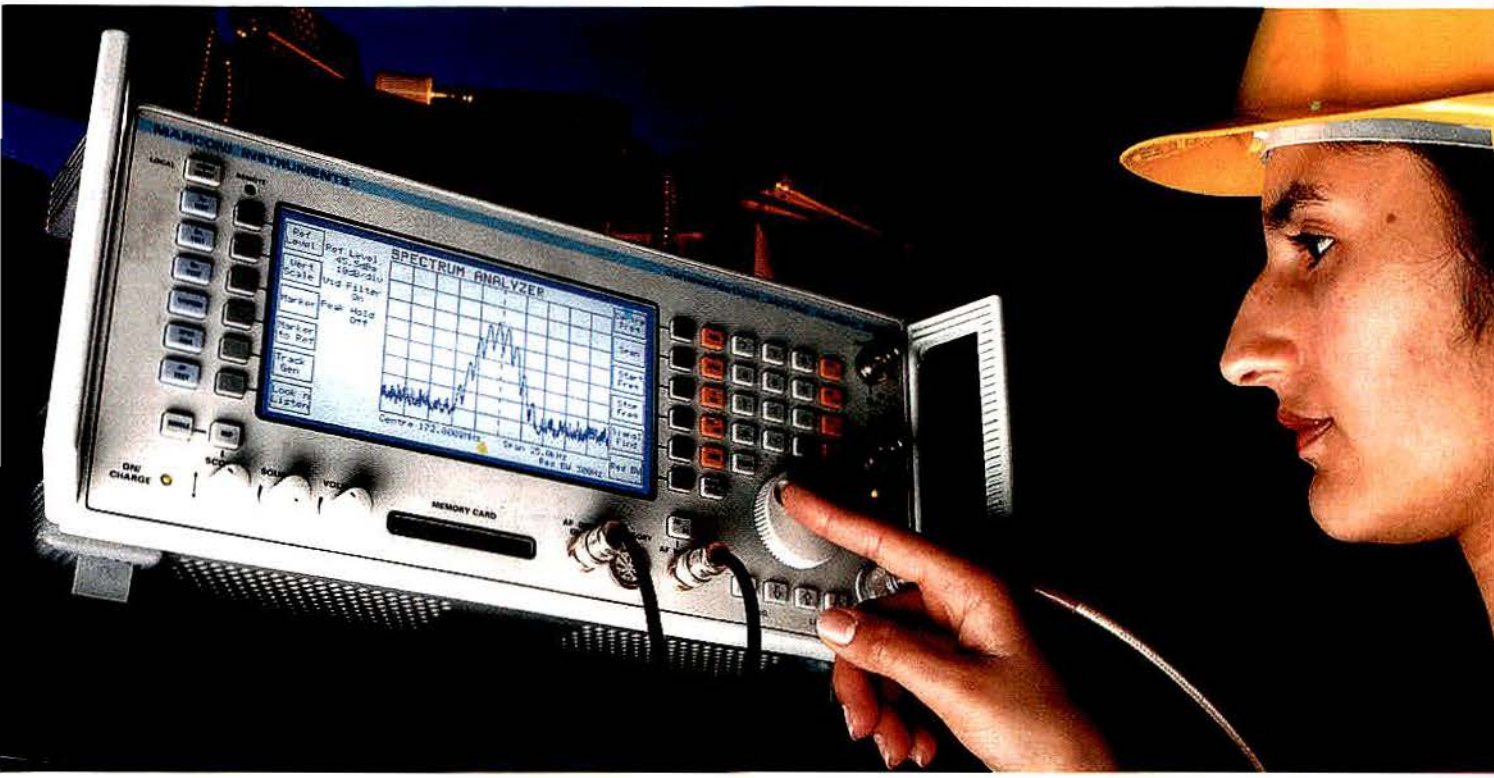


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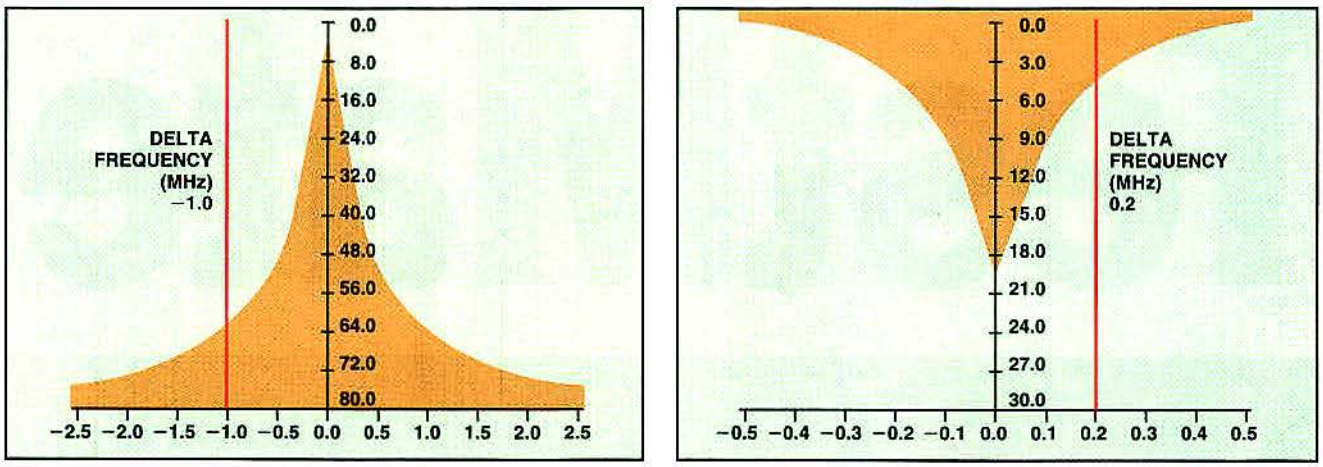


Figure 3. The typical frequency response curves of a band-pass and band-reject cavity filter.

Figure 2 illustrates the signal path.

If signals from the transmitters mix, an intermod product with an output level of about −11.7dBW would result, and a mobile unit on 163.4MHz passing near the site would be affected by this signal. The intermod frequency, 163.4MHz, is equal to two times transmitter B's frequency minus transmitter A's frequency, or

$2B - A = 163.4\text{MHz}$.

The acceptable levels of intermod products vary according to frequency band. At VHF, the acceptable level is −80dBW, and at UHF, −70dBW.

In this particular situation, an additional 68.3dB of attenuation is required to achieve the −80dBW acceptable intermodulation level to protect mobile and portable units near the transmitter.

How to achieve the required attenuation will be explained after the next (and more complex) situation.

▶ *Example No. 2* — Transmitters on same tower but different antennas.

The proposed transmitter A is on 154.20MHz with an output power of 16dBW, a line loss of 5.2dB, a bandpass filter insertion loss of 1.5dB and an omnidirectional antenna with 9.5dB gain 30 meters above ground.

The closest transmitter, transmitter B, is on 160.80MHz with a combiner with 5dB attenuation at transmitter A's frequency, a line loss of 3dB and an antenna with 7dB gain at 26 meters above ground.

In this case, a new variable is involved: the attenuation between the two antennas. Figure 1 reveals an attenuation of about 39dB for a spacing of 4 meters. Because the antennas are polarized vertically and spaced vertically, gain is not taken into account.

As in the first example, calculate the conversion factor as follows:

$$CF = 57 \log(1.5 + \Delta F) - (9.9) - (9\log\Delta F)$$

$$= 57 \log(1.5 + 6.6) - 9.9 - 9\log(6.6)$$

$$= 34.5\text{dB}$$

where

$$\Delta F = 160.8\text{MHz} - 154.2\text{MHz}$$

$$= 6.6\text{MHz}$$

The transmitter intermod level then is calculated as follows:

$$TIL = P_{TX} - (IL_{TX} + LL + AI + 2LL_M + 2FL_M + CF) + AG_M$$

$$= 16.0\text{dBW} - (1.5\text{dB} + 5.2\text{dB} + 39\text{dB} + 6\text{dB} + 10\text{dB} + 34.5\text{dB}) + 7.0\text{dB}$$

$$= -73.2\text{dBW}$$

where:



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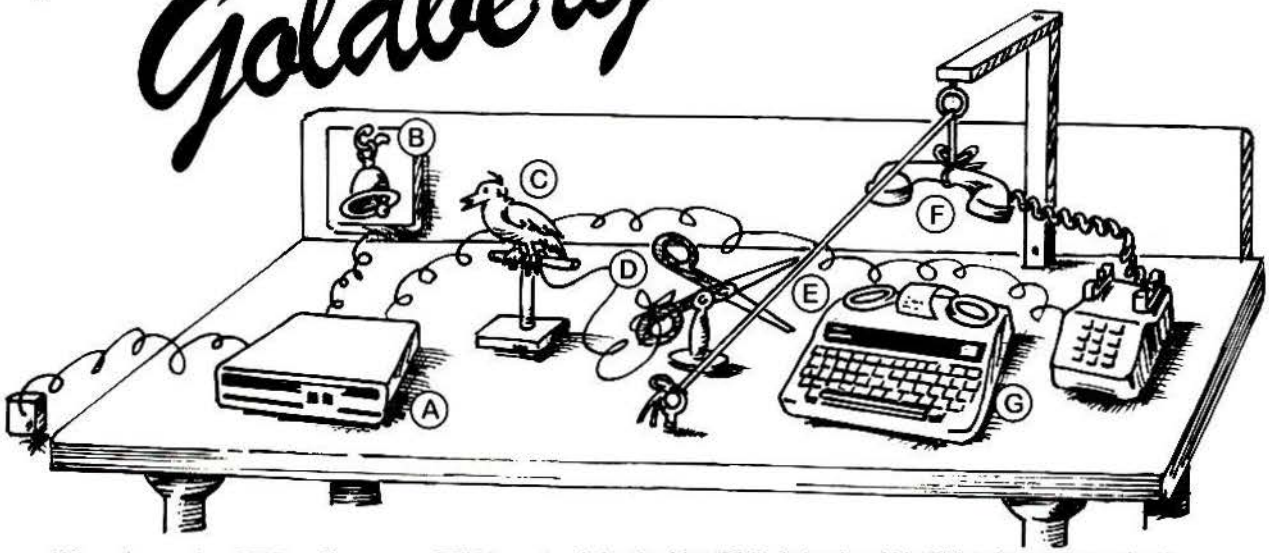
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P_{TX} = transmitter A power output

IL_{TX} = filter insertion loss at transmitter A

LL = transmitter A's feedline loss

AI = isolation between antennas

LL_M = line loss at mixer (transmitter B)

FL_M = filter loss (attenuation) of transmitter B at transmitter A's frequency. Refer to manufacturer's specifications to evaluate attenuation at desired frequency offset.

CF = conversion factor

AG_M = antenna gain of mixer (transmitter B)

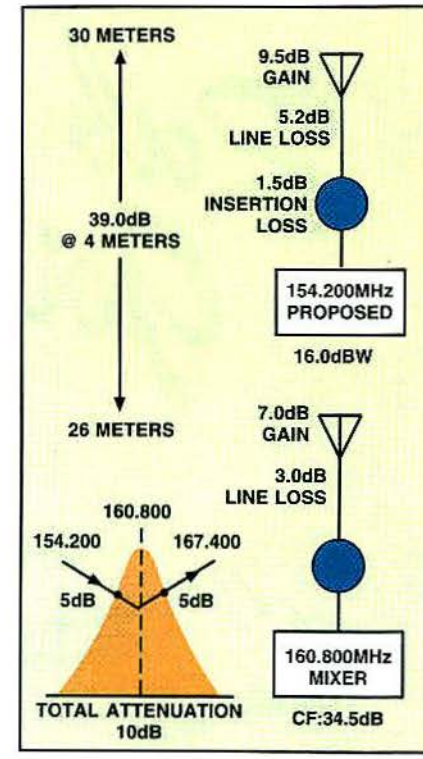


Figure 4. The signal path used in Example No. 2.

Figure 4 above illustrates the signal path.

An intermod signal at 167.4MHz will affect a nearby mobile when the transmitter outputs mix. Because the system works at VHF, an additional 6.8dB of attenuation is required to reach the acceptable −80.0dBW level.

Use judgment when only a small amount of attenuation remains to be achieved to meet the minimum requirement. Reality and theory often differ, and the equipment may perform better than the manufacturer's specifications.

The next, and last, example is the most complex. The principle is the same as in the previous cases, except the attenuation between antennas can be calculated as free-space loss. The equation for free-space loss in decibels is 32.3 + 20 log(frequency) + 20 log(distance in miles), but we will use the equation for free-space loss for distances measured in kilometers. Other new variables to consider are the antenna gain figures for transmitter A and transmitter B.

▶ *Example No. 3* — Transmitters on different antennas and towers.

The proposed transmitter A is on 158.0MHz with an output power of 21.0dBW, a line loss of 4.3dB, a combiner insertion loss of 3.2dB and an omnidirectional antenna with 8.0dB gain 34.5 meters above ground.

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Circle (52) on Fast Fact Card

is on 161.2MHz with a combiner with 12.5dB attenuation at transmitter A's frequency, a line loss of 5.2dB and an antenna with 9.5dB gain 37 meters above ground. The distance between the antennas is 30 meters (0.030km).

First, evaluate the loss between antennas. Because the antennas are separated horizontally, path loss and antenna gain must be taken into account, which was not the case with co-located, vertically separated antennas. The formula for path loss (PL) in decibels is:

$$PL = 28.2 + 20\log(\text{frequency}) + 20\log(\text{distance in km})$$

$$= 28.2 + 20\log(158.0\text{MHz}) + 20\log(0.030\text{km})$$

$$= 41.71\text{dB}$$

The conversion factor is:

$$CF = 57\log(1.5 + \Delta F) - (9.9) - (9\log\Delta F)$$

$$= 57\log(1.5 + 3.2) - 9.9 - 9\log(3.2)$$

$$= 23.86\text{dB}$$

The transmitter intermod level is:

$$TIL = P_{TX} - (IL_T + LL) + AG - PL + 2AG_M - (2LL_M + 2FL_M + CF)$$

$$= 21.0\text{dBW} - (3.2\text{dB} + 4.3\text{dB}) + 8\text{dB} - 41.71\text{dB} + 19\text{dB} - (10.4\text{dB} + 25\text{dB} + 23.86\text{dB})$$

$$= 60.47\text{dBW}$$

where:

P_{TX} = output power of transmitter A

IL_{TX} = filter insertion loss at transmitter A

LL = line loss of transmitter A

AG = antenna gain of transmitter A

PL = isolation between antennas (path loss)

AG_M = the antenna gain of mixer (transmitter B)

LL_M = line loss at mixer (transmitter B)

FL_M = the filter loss (attenuation) of the mixer (transmitter B) at transmitter A's frequency. Refer to manufacturer's specifications to evaluate attenuation at desired frequency offset.

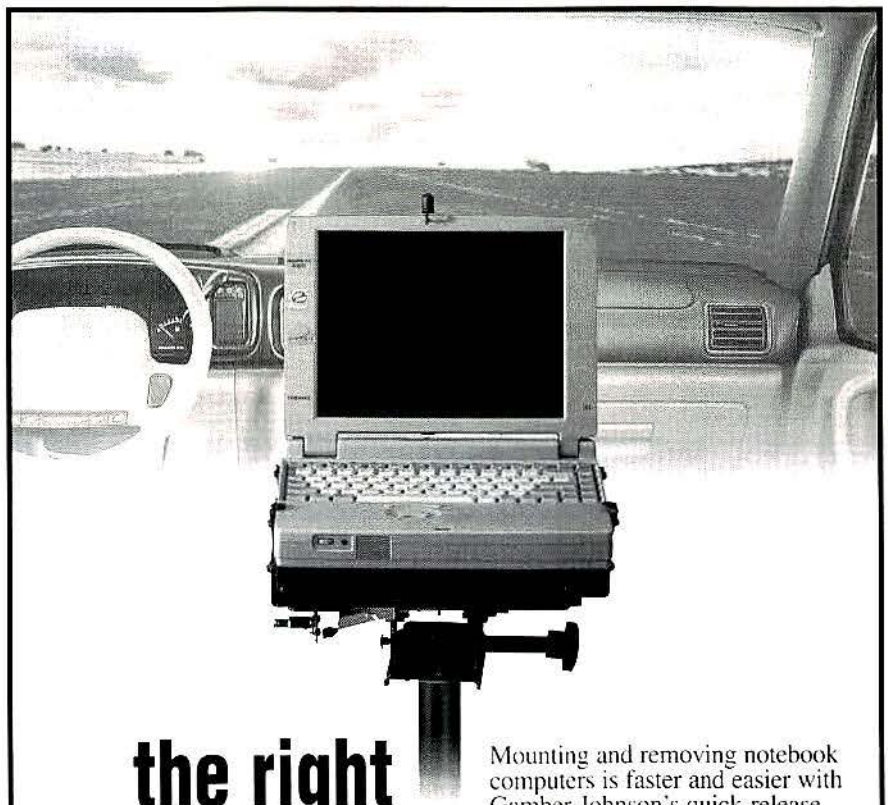
CF = conversion factor

An additional 19.53dB of attenuation is required to reach the minimum −80dBW signal level for VHF intermod. Figure 5 shows the path.

In this case, the antenna gain and line loss of the mixing transmitter is involved twice, because the incoming and intermod signals follow the same path. This is why they are multiplied by 2.

For obvious reasons, our examples used the same transmitter as being the closest in frequency and distance. This is rarely the case, but it is possible. Remember to conduct the same calculations by switching the mixing transmitter with the proposed transmitter so that both intermod possibilities are verified.

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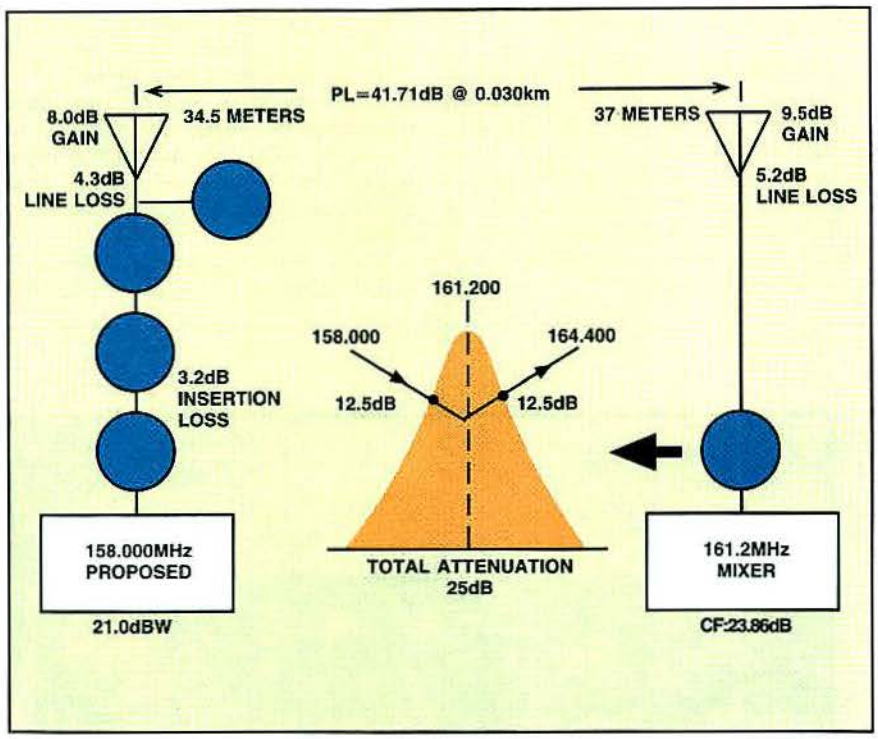


Figure 5. The signal path used in Example No. 3.

point is to increase the attenuation of the signal trying to reach our transmitter. To do so, band-pass filter cavities may be added to those already in use. They have the advantage of attenuating all other strong signals that may cause intermodulation. Another possibility is to use notch or band-reject filters, but they only offer protection against one specific signal and, unlike a band-pass, they do not offer any attenuation at the intermod product's frequency. When minimum insertion loss is important, though, one may prefer the notch filter.

For many, the ultimate device is an isolator or circulator, which acts as though it were a diode on the transmitter output. The insertion loss is low, and isolation is quite high, typically 40dB. Manufacturers offer them in dual packages, so isolation is doubled. They have the advantage of offering attenuation that does not vary with frequency spacing.

Reference

SYSPARC User's Manual, a computer program for antenna sites sold by the Department of Industry Canada.

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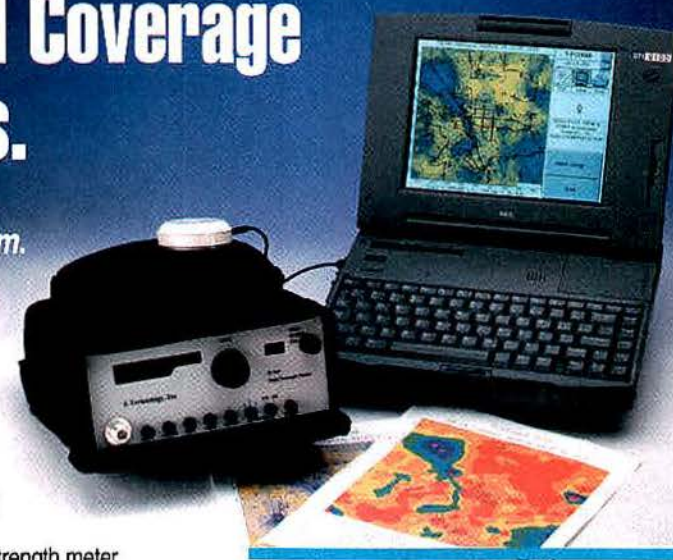
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Circle (54) on Fast Fact Card

Paging system monitor warns of system failures

Messages sent at regular intervals allow a remote-controlled switch with time-delayed outputs to monitor paging system operation and to send timely notification of system failures to your pager or to an alarm company.

By Eric Guth

As is typical of many paging entrepreneurs, Jeff Grazi serves as president, chief engineer and technician for his small company, Communications Unlimited, Denver. To maintain a competitive edge, he depends on system reliability and customer service. His greatest fear is a system-wide failure that goes unannounced until customers call to complain. By that time, a failed control link or paging transmitter may have been off the air for hours, and customers may have begun to shop elsewhere for paging service.

One solution for small paging system operators has been to monitor their channels continuously. For 10 years, Grazi used receivers in his office, home and car to monitor his three channels. This approach constantly consumes an operator's time and attention, instead of only requiring attention when a problem occurs.

An automatic and silent method of monitoring the network would be an improvement over active monitoring. For example, sending test messages over the network at regular intervals for decoding by an automatic monitor connected with an alarm would make it possible to detect a network failure soon after its occurrence.

My company devised an eight-output, remote-controlled switch that decodes alphanumeric and numeric POCSAG messages. Each output is individually controlled, and each can be programmed with a time delay ranging from one second to 12 days. An on-board serial port allows the switch to feed received messages into a personal computer, a printer or a moving-message electronic sign.

The remote-controlled switch is an industrial pager that receives the paging signal over the air and decodes the specific capcodes for which it is programmed. The eight remote control outputs operate from the paging message itself. The messages consist of a six-character password followed by a two-digit function code. (See Figure 1 below left.) Because the unit operates in either the alphanumeric or numeric mode, alphanumeric characters, both upper and lower case, can be used as the system password. To turn on output No. 1, the six-character password is sent, followed by the command "11" (output No. 1, *on*). To turn output No. 1 off, the command is 10 (output No. 1, *off*). A command of 91 or 90 turns all of the outputs on or off. In addition, each output time delay can be programmed independently so that output No. 1 can be set for five minutes, output No. 2 for 15 minutes, and so on.

For Grazi's purposes, he sends a page at regular 10-minute intervals. This page in turn resets a 12-minute delay on output No. 1 so it only times out when the specific page is not received by the remote-controlled switch after 12 minutes. By connecting the switch to unused inputs on his alarm system, Grazi is notified within a few minutes of a system failure. (See Figure 2 on page 62.)

The next step was to devise a way to cause the system to send the same paging message to the three remote-controlled switches on each of Grazi's three channels at the desired intervals, automatically. One solution was to use an external autodialer

Guth is co-founder and president of PageTap, Denver. PageTap manufactures the PT8-OC remote-controlled switch described in the article.

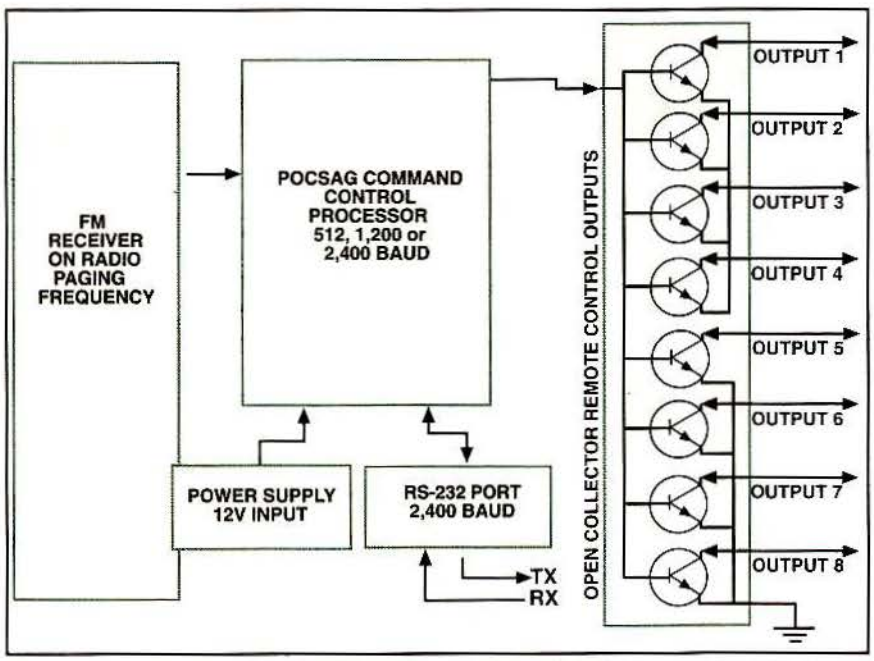


Figure 1. A block diagram of the PT8-OC remote-controlled switch. Eight outputs have individually programmed time delays ranging from one second to 12 days.

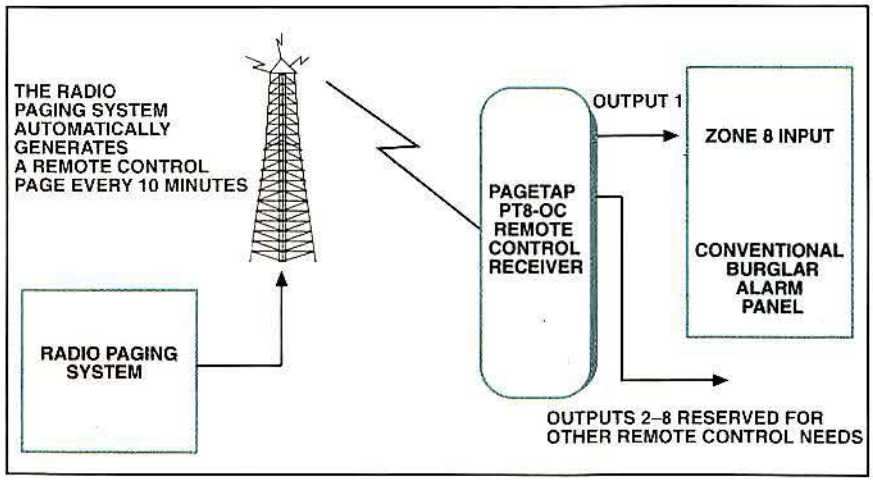


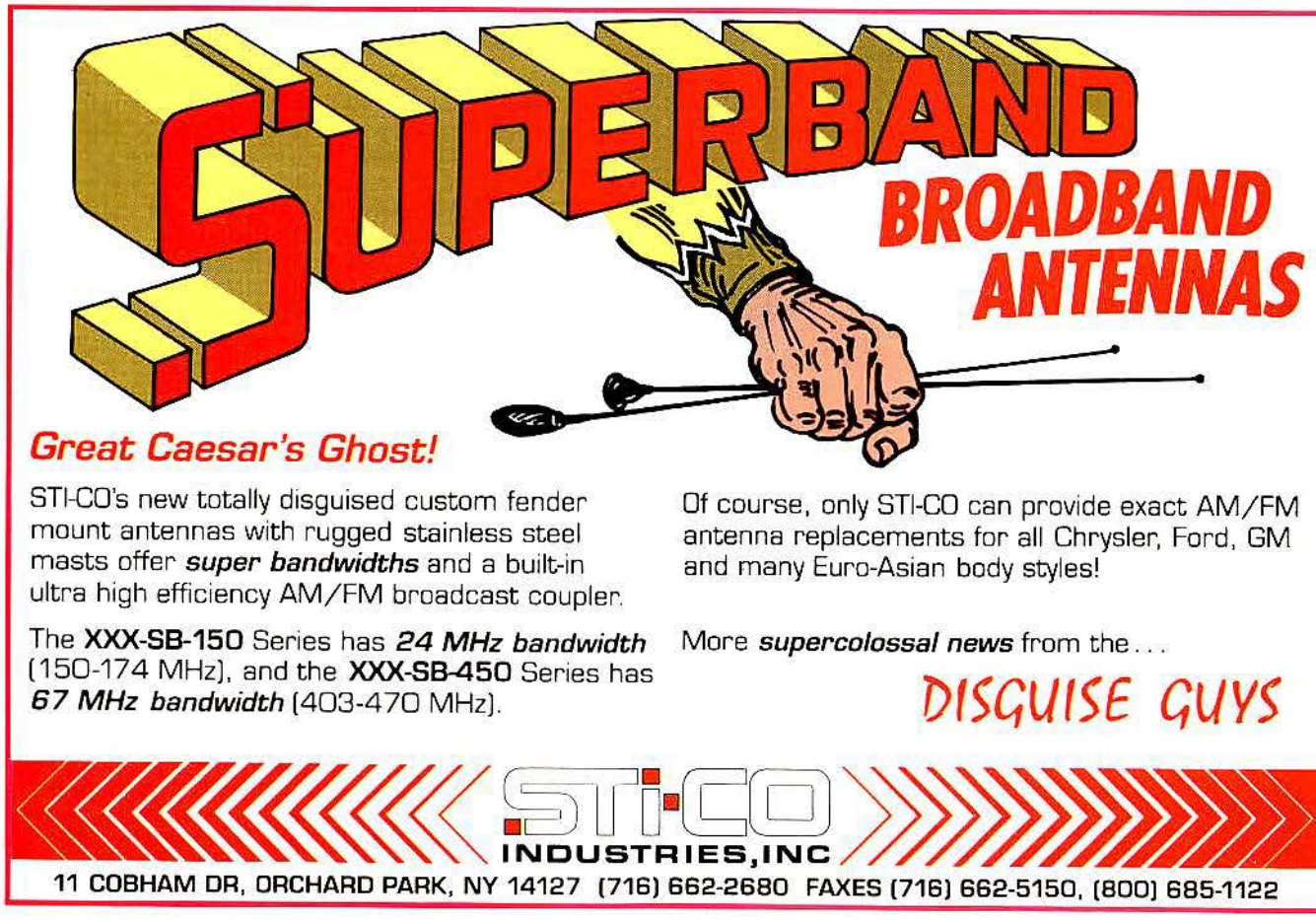
Figure 2. A block diagram of the remote-controlled switch as configured for use at Communications Unlimited, a paging company in Denver.

with a timer that causes it to dial a paging number to drop a message every 10 minutes. This single paging number was chained together to allow pages to be sent on all three channels simultaneously. This method allows each in-bound direct inward dialing (DID) trunk to be tested, as well as the system itself. However, it requires a dedicated telephone line and the associated monthly expense.

By studying the programming manual for his Unipage paging terminal, Grazi found that he could generate the page automatically from the TNPP (Telocator Network Paging Protocol) card in the terminal chassis. This method eliminates the need for outboard equipment and the phone line, and it operates forever or until the programming is changed.

The first test site for the remote-controlled switch used at Communications Unlimited was at Grazi's home, where it was connected to one of the unused zones on a burglar alarm. The use of only one output was required for monitoring the paging system. The other outputs were used to control the furnace, hot tub and electric blanket! With the time-delayed outputs set for a few seconds, Grazi could use his cellular phone to adjust his home electronic thermostat in five-degree increments while driving home.

The home alarm monitoring company was informed that an alarm on "zone No. 8" required that Grazi be notified immediately of a system failure. It worked, and the first time after installation that the paging system failed and the remote-control page was not received within the 12-minute window, Grazi was alerted by the alarm company of the system failure. That part was satisfactory. In addition, though, Grazi was met by Denver police officers as he backed his vehicle out of his driveway, on his way to check the paging system. Another call to the alarm company with another explanation of "zone No. 8" alarms prevented further armed



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Paging sentry

An automatic paging sentry used by Communications Unlimited, Denver, helps company owner Jeff Grazi respond quickly to paging system failures without having to monitor the system with scanners. On a Sunday afternoon, Grazi and his fiance were at a movie theater with popcorn and drinks in hand, watching a film. Grazi's alarm pager began to vibrate with not one, but three messages, indicating that all three of his paging channels were off the air.

Grazi and his fiance left the movie and drove to his office. After making sure that the system's link transmitter was operational, he went to the hilltop transmitter site where he found that lightning had shorted a surge protector in the main ac power feed, causing the breaker on the transmitter's power circuit to open. He replaced the surge protector with a spare. A small disaster had been averted, and not a single customer had called to report the outage. Grazi's use of the remote-controlled switch to monitor his paging system had paid for itself in peace of mind and customer goodwill.

—Eric Guth

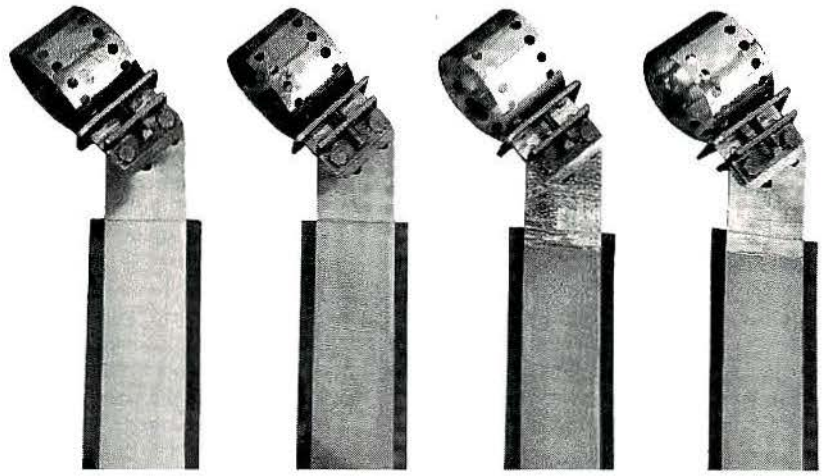
police responses to a paging system failure.

Grazi since has installed other remote-controlled switches in other cities to act as his sentry against system failures. Because the 10-minute page is a general broadcast, all of the remote-control receivers can be reset simultaneously with the same page.

Grazi plans to install the remote-controlled switch at hospitals served by his system so hospital employees who depend on paging for emergency calls can be notified immediately of a system failure. During the interim, they can use the public-address paging system as a backup until the radiopaging system once again is operational.

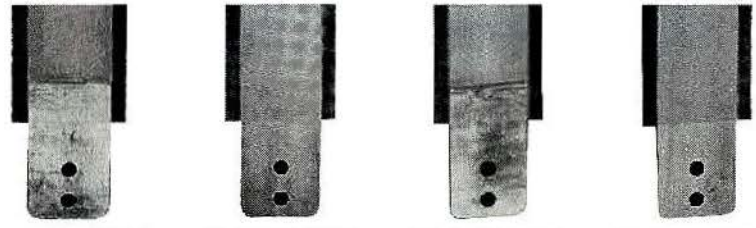
The sounds of paging signals no longer intrude on Grazi's personal time. His secretary reports that, with his newfound freedom, Grazi can spend less time in the office. Grazi himself reports a new lease on life, including being able to sleep a full night without the background noise of his scanners and the ability to pursue his half-dozen other businesses while the remote-controlled switch keeps watch over his paging system.

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This way to the egress!

By Robert H. Schwaninger Jr.

There probably was no greater showman than P. T. Barnum. His sense of the extravaganza was unmatched in the 1800s. Barnum could draw thousands of curious folks to see Cheng and Eng, the original Siamese twins; Major Tom Thumb, his diminutive moneymaker; and Jenny Lind, the Swedish Nightingale who enchanted audiences with her beautiful voice.

Yet, despite his ability to draw crowds to the halls and arenas he had specially constructed for his troupe of freaks, curiosities and wonders, Barnum had a serious problem. Once he collected their admission, he had difficulty getting the crowd to exit the building. So fascinated were the public in his sideshows, they wouldn't leave promptly, allowing the next group of customers to pay and enter.

Barnum, ever the brilliant manipulator of people, devised an "exit strategy" to help him keep the turnstiles going. On the rear exit door he painted the words, "This Way To The Egress!" in bold letters. His customers were not all sufficiently sophisticated to appreciate that the word "Egress" meant exit. So, Barnum's customers blithely passed through the door hoping to see the exotic, three-headed Egress that they were sure lurked on the other side.

Today, many industry commenters are advising small operators to come up with an "exit strategy." As with Barnum, the strategy is supposed to allow the strategist to make additional money. The problem with the industry advisers' opinions is that it is difficult to discern who, in their respective scenarios, is playing the part of Barnum, and who are the reubens. Many of the commenters appear to be advising the customers to paint the back door with the witty ruse, then pass through the same door to oblivion. In older days, some of these well-meaning folks would be called shills.



Over the years, I have advised clients on how to cash out. After all, no one should be forced to stay in the business, particularly if another company is willing to pay handsomely to buy assets. In each such instance, I advised my clients that leaving the business or selling some asset should be a *choice*, not a requirement. Each

Schwaninger, *MRT's* regulatory consultant, is a partner in the law firm of Brown and Schwaninger, Washington, DC. He is a member of the Radio Club of America.

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operator should be fully entitled to say, "no thanks," and go on operating, building, competing and thriving.

Lately, some industry commenters appear to be stating that small operators should prepare to exit the business. These same commenters don't explain where these displaced operators should go or what they should do, but whatever it is (in the commenters' view), it won't be selling land mobile services. Not so oddly, many of these commenters serve as brokers or agents of purchasers, and those commenters won't make a dime if small operators don't continue to participate in the consolidation movement throughout the industry.

Well, I'm a trendy guy. If an exit strategy is the latest "must have" for small operators, then I'm going to give each and every reader an exit strategy that you all can live with. With a few simple tips, each of you can prepare for the day that someone comes knocking on your door and tells you, "time's up."

First, lock up all of your customers to contracts for services. That way when a large competitor comes into your market and starts raiding your customer base, you can sue the hell out of them for tortious interference with a contract. Second, check to make sure that large competitors aren't making inaccurate claims about your business in the marketplace to lure customers onto their system. If they do, sue the hell out of them for business libel. Third, if a large competitor begins creating harmful interference to drive you off a given frequency, sue the hell out of them for business torts, including creation of a private nuisance. Finally, if the efforts of a carrier are clearly designed to engage in unfair practices to monopolize a market, sue the hell out of them for violations of the antitrust laws.

Make sure that the large competitor constructs what they have claimed to construct: applies only for facilities that are spaced far enough from any protected facility you operate; follows the FCC rules as faithfully as the FCC would demand from you; and generally engages in lawful compliance with the FCC's application, construction and operation rules. If they don't, point out each violation to the FCC, and request that the large operator receive sanctions, forfeitures and cancellation of authorizations.

If you are wondering, "where's the exit strategy?" you've missed the point. There's more than one way to exit. There's the generally recommended method of waiting until the value of your business has been eroded through unfair regulatory and business practices until any eventual purchase offer is so small that you wonder why you've been busting your backside for years in building your business. Then there's the exit strategy that includes a premium paid for a business that stands clearly and forcefully in the way of a corporation's big plans. It's harder (and more expensive) to knock a guy over who's dug in his heels.

Smart business demands that you keep as close an eye on your competitor as you do on your own business ...

Your exit strategy has to be based on getting *at minimum* full value for your assets. You cannot hope to achieve this goal if the value of your radio systems has been eroded by neglect. The most common form of neglect for small operators is a failure to inventory the efforts of competitors. That would be like GM not checking out the new Fords. Smart business demands that you keep as close an eye on your competitor as you do on your own business, particularly if your competitor is a large, dominating carrier.

Your exit strategy is weak if you can visualize going into negotiations with your hat in hand, begging your competitor for pennies. It's strong if you are positioning your company to be a fortress of dynamic licensing, sales, site acquisition, personnel and marketing, where suitors are forced to come to you. Your success should never depend on the charity of others.

P.T. Barnum had an exclusive contract to showcase Jenny Lind in America. Tom Thumb was Barnum's employee, no doubt including a covenant not to compete. Barnum's business was joined solely to Barnum as closely as Cheng and Eng, and no competitor was going to be able to break the ties that Barnum built carefully to assure his continued success. Those are the exit strategies that worked for Barnum and that will work for all operators throughout the industry.

Don't be fooled by the flim-flam artists who preach an exit strategy that doesn't include your full success. All they are saying is "This Way To The Egress!"

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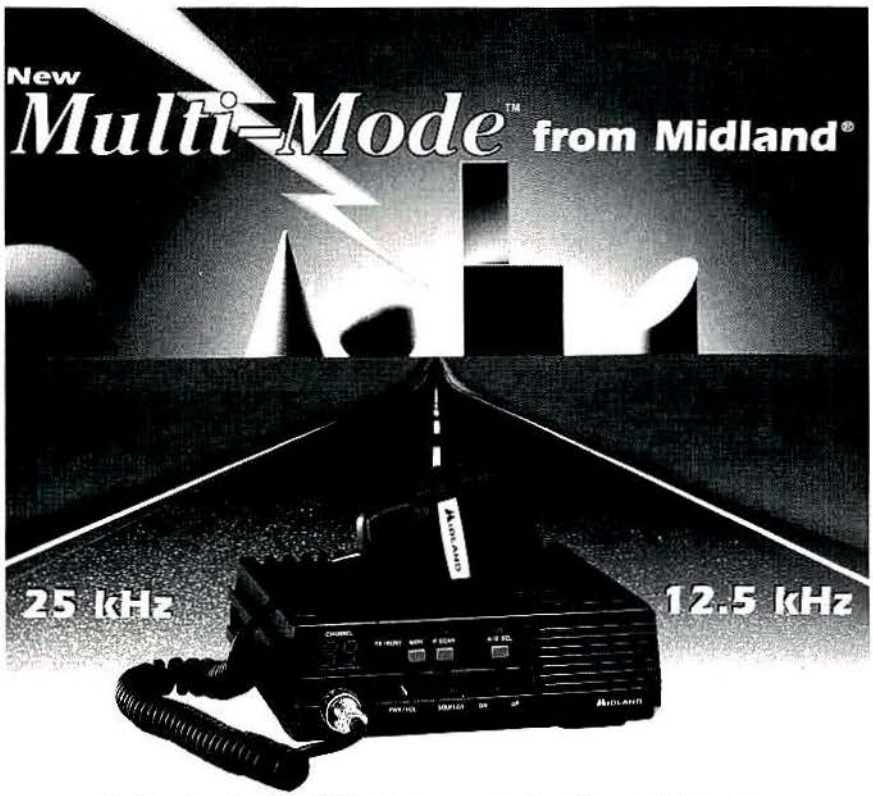
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220MHz system owners unite in 'strength in numbers' approach

The first meeting of the newly founded National SMR 220 MHz Managing Partners Association was held in Las Vegas in June. The association's aim is to maintain a "strength in numbers" approach to attract the best management companies and equipment suppliers. Benefits in joining are the retention of one attorney, coordination and dissemination of activities and information, agreement negotiation from a position of strength on a group basis, cash reserve for legal battles, political clout when going to the FCC for any problems or complaints that might arise at sites and equipment purchases at reduced bulk rate prices.

More than 50 companies with SMR 220MHz sites were represented at the meeting, and several management companies were invited to give presentations of their services.



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Nextel orders iDEN technology

Nextel Communications, McLean, VA, is placing an order worth slightly more than $100 million for an improved version of Motorola's integrated dispatch enhanced network (iDEN). Along with infrastructure equipment, Nextel has ordered 100,000 compact handsets, which Motorola calls the i360 and which Nextel will market as the PowerFone.

Pilot pricing for the smaller, digital unit is about $400, which does not include various trade-in allowances and further cost-reduction opportunities. Pricing in Nextel's initial Chicago pilot program is competitive with cellular pricing, but the new service has the additional features of instant conferencing, text messaging and voice mail.

In a memorandum of understanding, Motorola has agreed to give Nextel flexible terms for the existing equipment and infrastructure and credit totaling $685 million available for purchases Nextel intends to make on a nationwide basis.

Chadmoore acquires stock in CMRS Systems, 800 SMR Network

Chadmoore Wireless Group, Las Vegas, has acquired stock of CMRS Systems and 800 SMR Network in a transaction valued at more than $34 million. Through the acquisitions, Chadmoore obtained 10-year management rights and options to acquire channels nationally, bringing the total number of channels under contract by Chadmoore to more than 7,000. The respective service areas of CMRS and 800 SMR Network will increase Chadmoore's service capabilities in each of its underlying markets, with a potential of operations in every state. The $34 million in consideration is comprised of $3.5 million in cash, with the balance in stock and options.

E.F. Johnson supports SMR WON

E.F. Johnson, Burnsville, MD, has announced its support of the Specialized Mobile Radio Wireless Operator Network (SMR WON) and the association's efforts toward promoting an industry consensus plan for resolving the controversy surrounding 800MHz licensing and rulemaking. SMR WON has been a participant in drafting an industry consensus proposal with the American Mobile Telecommunications Association (AMTA), Nextel Communications, McLean, VA, and with the support of the Personal Communications Industry Association (PCIA) before the FCC in the matter of 800MHz licensing.

PCSI chip set allows development of compact paging devices

PCSI, San Diego, will begin offering a chip set for pACT (personal air communications technology), a narrowband PCS technology for wireless paging and two-way messaging applications. Sample quantities are expected to be available in the third quarter of this year and volume production in the first half of 1997.

pACT is an open protocol that allows carriers to increase system capacity as demand dictates. It also provides a migration path to a variety of high-volume, low-cost, advanced data messaging applications, such as acknowledgment paging, two-way messaging and telemetry. PCSI's chip set will allow pACT subscriber device manufacturers to produce small, low-cost personal communications devices with long battery life.

The three-component chip set consists of a control processor IC, a modem IC and a radio IC. Along with the chip set, PCSI provides a radio reference design, the pACT protocol stack and a software development platform designed to shorten original equipment manufacturer time to market.

Survey covers four main areas of wireless technology

The Yankee Group, Boston, MA, has tabulated the more than 2,000 responses from its 1996 *Mobile User Survey*. The survey includes questions on the respondents' work environment, mobility patterns and interest in wireless devices and services. It covers four areas of wireless technology: cellular, paging, portable computing and personal communicators.

Some highlights of the findings include:

- 48% of pager users carry their device on weekends or after work.
- 66% of portable computer users think it is important to have ubiquitous, nationwide wireless data coverage.
- The typical cellular phone user makes 10 phone calls every week.
- 60% of cellular users make the majority of their phone calls within their metro area; however, 58% of cellular users agree that having nationwide coverage is important.
- At what price point would cellular subscribers use their service significantly more? Fifteen percent would if prices were 10% lower; 77% if 50% lower.

The results were made available immediately to Yankee Group clients, with information on penetration rates, attitudes toward wireless technology and usage of telecommunications services and consumer electronics technologies both at home and at work.

Signal introduces enhanced mobile workstations to South Florida

Signal Communications, Pompano Beach, FL, has been selected as a dealer-partner to represent the Geotek product line within the South Florida market. Signal has begun to offer digital wireless communication network services to Dade, Broward and Palm Beach counties.

Signal has installed Geotek enhanced mobile workstations for its sales and service staff as demonstration units. The mobile workstation is an all-in-one device that combines the functions of a cellular phone, two-way radio, pager and laptop computer. In addition to telephone and dispatch voice communications, the workstation offers software that includes automatic vehicle location, data dispatching, two-way messaging, credit card verification, point-to-point travel directions and access to customer databases.

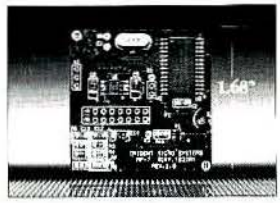
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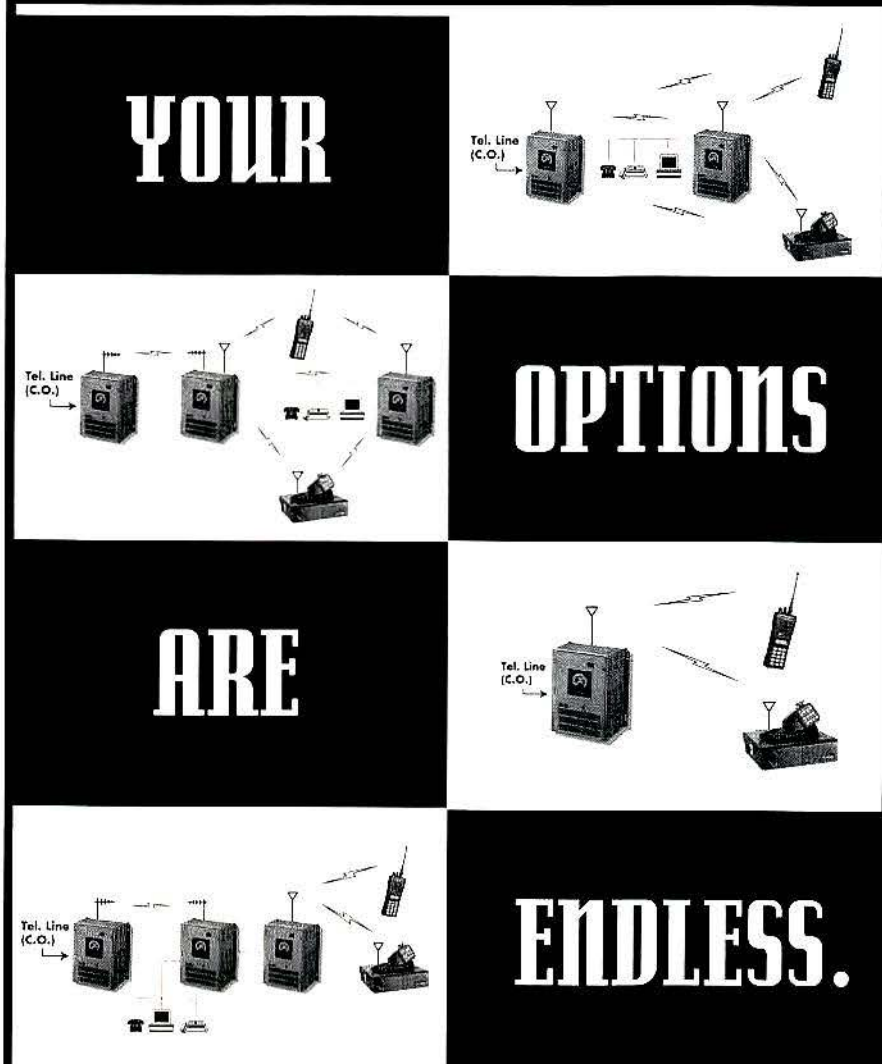
Independent SMRs select ESAS protocol standard

Wireless Professional Communications Service (WPCS) hosted a two-day meeting, June 20–22, in Portland, OR. Fifteen manufacturers and 30 wireless operators from across the country gathered to discuss plans for implementing the ESAS standard for enhancing analog systems. The protocol was developed in response to dealers' needs to add features to LTR analog systems. Uniden, Fort Worth, TX, is promoting ESAS as an open standard by encouraging licensing among suppliers.

The meeting featured presentations from manufacturers showing support of WPCS by their decision to provide ESAS-compatible products. Zetron, Redmond, WA, is introducing its ESAS-compatible FastNet switch along with ESAS upgrades for existing controllers. Zetron, IDA, Fargo, ND, and others are producing ESAS billing packages. Maxon, Kansas City, MO, unveiled a duplex ESAS portable available for delivery the fourth quarter of 1996. Standard Communications, Los Angeles, announced full support of WPCS and its development of ESAS equipment. Kenwood Communications, Long Beach, CA, and Kenwood Systems Group, Friendswood, TX, both underlined their commitment to supporting WPCS and announced their evaluation of the ESAS network beta site in Michigan.

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Central Virginia municipalities sign agreement with Ericsson

The Central Virginia Regional Radio System committee signed a contract with Ericsson, Lynchburg, VA, for a $11.7 million radio system that will bring seamless communications coverage to the four participating municipalities' public safety agencies.

According to community officials, users will have access to more advanced services, and taxpayers will save about $23 million by sharing tower sites, maintenance fees and other infrastructure costs.

Ericsson will provide its trunked technology to the cities of Lynchburg and Bedford and the counties of Bedford and Amherst, all of which are co-owners of the system. The system will consist of six sites, support about 1,700 users and cover an area with a population of about 150,000.

PageNet opens distribution center for national accounts division

PageNet, Dallas, has moved its distribution center for its National Accounts Division. The new fully automated, 62,000-square-foot facility houses a new packaging and distribution system that will allow the center to supply as many as 30,000 packages of pagers a day, as well as to handle returns.

Celwave sponsors golf contest

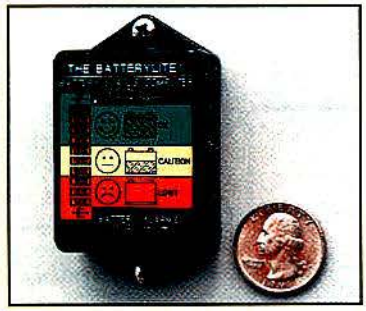
The Great Tee Off, a contest featuring a computerized golf simulator, raised more than $1,300 for the Radio Club of America Grants-in-Aid fund. Celwave, Marlboro, NJ, sponsored the competition during the International Wireless Communications Expo in Las Vegas.

Prize winners were Bo Ray, manager of the Utilities and Industrial Systems Division of Zetron, Richmond, WA, and Erica Hale, customer service and administrative sales manager for Telecommunications Power Systems, Randolph, NJ.

Readers' choice

Of all the new products and services in the January 1996 issue, the one reprinted here generated the most reader requests for additional information. If you missed it the first time, here is your opportunity to acquire more information on it. Just circle the corresponding Fast Fact Card number on the card found in the back of this issue and mail the card to us.

Battery monitor provides condition readout



The Battery-Lite informs any lead-acid battery user of the battery's condition. The unit from **Photron** draws less than 0.005A but provides a battery state-of-charge (SOC) readout in percentage along with SOC trend and 10 critically important battery conditions. The palm-size unit requires 2–4 small-gauge wires for hookup and is available in surface-mount and flush-mount versions.

(Circle 500) on Fast Fact Card)

Stackable aluminum cabinets offer mounting options



The ST (stackable) series of aluminum base station cabinets from **DDB Unlimited** are available in 34" (double-deep) or 17" (single-deep) configurations. Stacking combinations of the 19" rack-mount cabinets allow heights ranging from 30" to 84". Double-deep cabinets are equipped with "slam-latch" doors on both sides. The doors are completely housed to prevent unwanted entry and to provide filtered ventilation. The cabinets are finished with a baked-on powder paint to prevent chipping and scratching.

Circle (401) on Fast Fact Card

Alpha paging port expander provides more speed

The TAP2000 alpha paging port expander from **Hark Systems** offers higher baud rates and enhancements to the TAP200 series. A TDD access feature makes a system ADA-compliant without additional lines or modems. The TAP2000 modem cards are available in a 2,400bps version and an optional 14,400bps version. Both versions can be used in the same system.

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Repeaters -The RRX Series UHF Programmable Repeater offers high performance specifications, CTCSS/DCS, a wide range of options and an affordable price.

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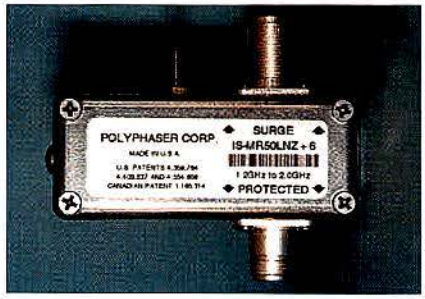
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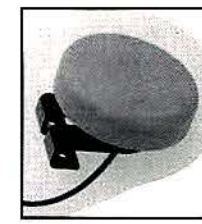
Coaxial protector guards active-antenna GPS receivers against surges



PolyPhaser has introduced a coaxial protector for GPS receivers with active antennas. The IS-MR50LNZ+6 protects in-line amplifiers and GPS receivers, providing optimal protection for dc and RF paths on coax. With positive and reverse voltage protection, the unit exhibits low loss and low VSWR over a large bandwidth.

Circle (403) on Fast Fact Card

GPS antenna receive technology comes in active, passive versions



The **Maxrad** GPSA (active version) and GPSP (passive version) global positioning system antennas offer active or passive receive technology in an impact-resistant, dove-gray polymer shell. The antennas are designed and constructed to meet or surpass all of the current design specifications and will directly replace any similar antenna currently available. Various antenna-mounting options and configurations are available. BNC connectors are standard; other connectors are available on request.

Circle (404) on Fast Fact Card

Power amplifier series combines with plug-in base station board

The Eagle series of high-, medium- and low-power base station and link transmitter power amplifiers are designed to operate with any FCC type-accepted exciter. The amplifiers from **Eagle Telecom International** can be combined with an optional plug-in base station board to provide a complete base station in the same volume as the power amplifier. The rack-mount, modular design units have analog and digital capability. Units for more than 100W are equipped with thermal control. The units are compatible with both RCC and PCP systems.

Circle (405) on Fast Fact Card

Synthesized 20-channel portable includes coded, analog squelch



Fanon Courier's M510 VHF portable FM transceiver includes built-in CTCSS and DCS squelch controls. The 5W, 20-channel radio is designed for in-building security and construction site applications. Options for the synthesized, programmable transceiver include a hands-free headset, vox control unit with belt-clip, single drop-in quick charger and leather cases.

Circle (406) on Fast Fact Card

Portable Power!



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The EC Series units are designed to be compatible with Bendix/King portable radios. A specially designed side connector enables a true "jerk & run" operation. Models offered include VHF and UHF chargers with 50 watts RF amplification across the band.

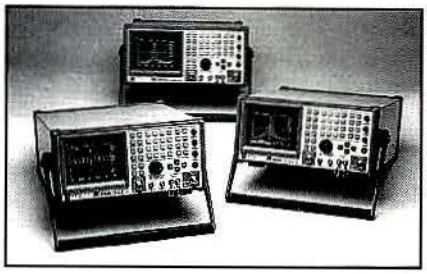
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Circle (64) on Fast Fact Card

After-market macro library expands functionality of spectrum analyzers



The **IFR Systems** Applications Software Group offers a macro library that expands the functionality of the company's AN900 series spectrum analyzers shown above. The P/N AC1046 macro library includes 10 programs to expand general and cellular test capabilities. For cellular testing, the firmware features macros for measuring adjacent channel power (complete with an ACP graph mode), cellular channel mode and occupied bandwidth. For general testing, macros include VSWR and cable fault. Additional features include pulse identification, noise marker, and carrier/noise normalized to either 1Hz or 1.23MHz.

Circle (407) on Fast Fact Card

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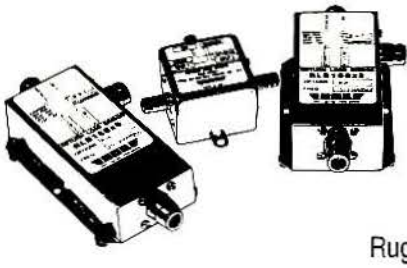
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Circle (68) on Fast Fact Card

VSWR BRIDGES & TEST CABLES



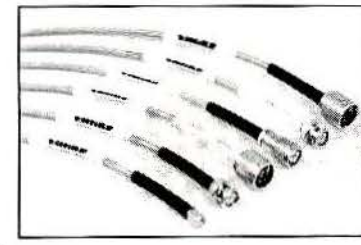
FEATURES:

5 watt power
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Rugged construction

Using the EAGLE return loss bridge allows frequency domain reflectometry tests to be made easily and inexpensively. There is no need to spend thousands of dollars on a dedicated antenna tester. Simply use the EAGLE bridge with your present spectrum analyzer and tracking generator. This technique is described in our free application note. See offer below.

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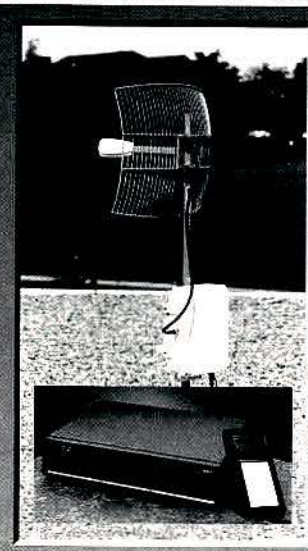
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See us at the 62nd APCO Conference & Expo in San Antonio, Booth #1900

Circle (67) on Fast Fact Card

New products

Bandpass cavity filter targets paging interference



The model BP-500 from **Radio Control Systems** is an 8" OD three-quarter wavelength coaxial cavity filter designed for use with paging transmitters or receivers operating from 928MHz to 932MHz. The filter is available as a single cavity or as a multiple-cavity combination. The multiple-cavity models are supplied with interconnecting cables and are mounted on panels for 19" rack mounting. Also included is a heavy-duty wall-mount bracket. The unit uses 7/16 DIN connectors and has an input power rating of 500W.

Circle (408) on Fast Fact Card

Paging, voice mail controller expands with operator



Linktronic Systems' InfoLink-2000 Paging and Voice Main Controller is a multipurpose communications controller using computer and digital signal processing technology. Features include window-based graphic user interface, a larger system disk and memory storage for user databases and voice files. Users can access both the voice mail and paging sub-systems with a single phone call. Users can define their own access preference, message notification schedule, greeting messages and mailbox tree. The InfoLink-2000 is designed to expand from four trunks to 128 trunks to accommodate operator expansion. Both POCSAG and Golay paging protocols are supported, as well as selectable baud rates.

Circle (409) on Fast Fact CArd

Anchor bolt mount installs without drilling holes



The SDI1584 Universal Anchor Bolt Mount allows the installation of two-way and cellular equipment without drilling mounting holes. The mount from **Scientific Dimensions** fastens with anchor bolts holding the front passenger seat. The heavy-gauge, powder-coated steel mount reconfigures to accommodate most automotive seat bolt patterns. Low-lying and out-of-the-way of vehicle airbags, the mount is compatible with both the SDI Goosnek Flexible Pedestal Mounts and the Series 5000 Rigid Pedestal Mounts.

Circle (410) on Fast Fact Card

Jumper cables provide short interconnect solution



LMR Flextech jumper cables from **Times Microwave Systems** are designed for short interconnect needs in wireless communications systems. The weatherproof jumpers are fabricated from LMR-600 cable, which has loss similar to a ½" LDF cable with flexibility better than a ½" superflexible cable. The jumpers are also available with LMR-400 or LMR-900 cable. The jumpers are available with a range of connector interfaces including N, 7/16 DIN, ⅞" EIA, TNC and UHF. Hex-coupling nuts and silver-plated connectors with gold center pins are standard. Loss of less than 0.3dB and VSWR of 1.15:1 to 2GHz is guaranteed.

Circle (411) on Fast Fact Card

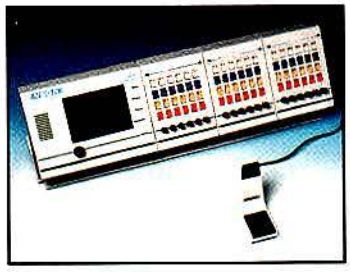
Desktop logger records 16 hours of voice messages



Omnicron Electronics has introduced a compact series of professional voice logging recorders to upgrade its VLR series. The recorders provide automatic documentation of two-way radio and telephone messages. The recorders feature slow-speed recording to allow 16 hours of talk time on a standard audio cassette. A time track option documents time and date on a separate channel. Additional standard features include vox recording, alarms to prevent operator error, tape position counter, dual headphone jacks and automatic record level circuitry.

Circle (412) on Fast Fact Card

Touch-screen console handles radio, telephone



Model C-6024 control console from **Vega Signaling Products** features a touchscreen and independent switches for line selection and instant PTT. With microprocessor control, the multiline, multiformat console can handle as many as 24 lines. Any line may be configured for either a dedicated two- to four-wire radio circuit, a dial-up access telephone circuit or a full-duplex PSTN telephone circuit. The system offers TLM (sequential tone line modules) to allow the operator a site for transmission and DLM (dial-up access modules), which allow the operator to select a dial-up site for transmission. PLM (telephone line modules) answer or initiate a call on the PSTN. The system is easily expandable by adding the appropriate number of switch panels, each of which accommodates six line cards.

Circle (413) on Fast Fact Card

Swivel option increases range of mounting positions



SMC Electro-Mount has developed the Dash Pro Plus swivel assembly option for its line of Dash Pro mounting brackets. The swivel quickly and easily attaches to any Dash Pro bracket. The mounting plate on the swivel assembly can be adjusted to provide more positioning options for equipment.

Circle (414) on Fast Fact Card

D istribution

The Kenwood DCS series analog and digital storage oscilloscopes are available from **Print Products International.** Kenwood Test & Measurement Instruments are exclusively imported from Japan by Print Products International.

For more information, call 800-638-2020

Sinclair Technologies has announced the appointment of **Primus Electronics** as a Sinclair and Sinclabs Distributor. Primus represents those companies in the Central and Pacific Northwest regions of the United States.

For more information, call 800-892-1413, Central region, or 800-279-8306, Pacific Northwest region

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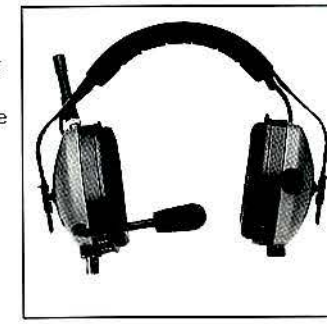
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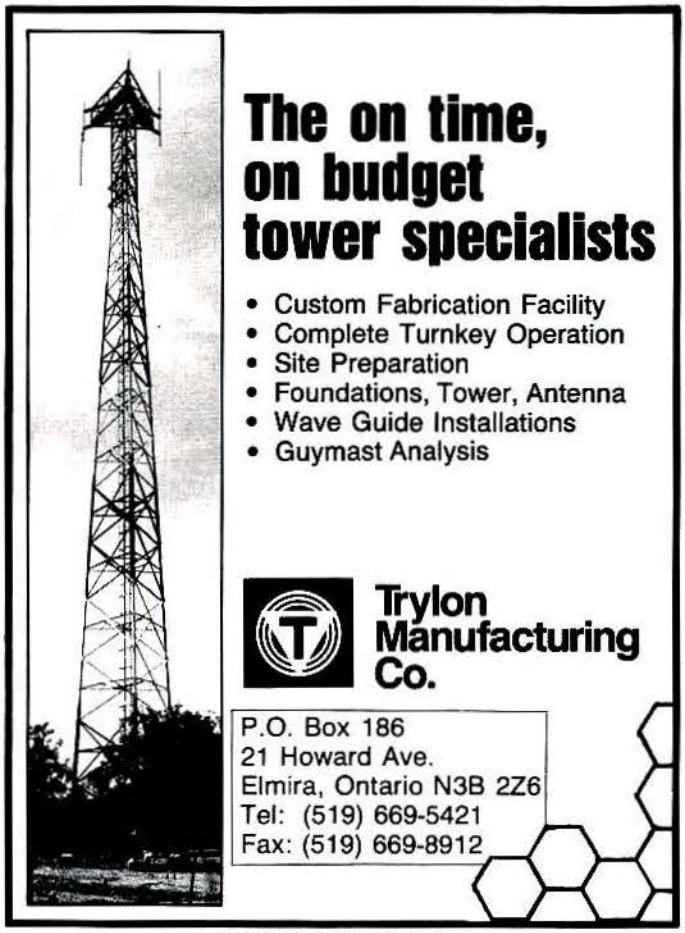
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Circle (69) on Fast Fact Card **Visit us at APCO, Booth #1120.**



Circle (70) on Fast Fact Card



Circle (71) on Fast Fact Card

People


Powell


Winters


Henderson


Kabeche

Keith Powell leaves PageNet, Plano, TX, as vice president and general manager to join Paging Partners, Freehold, NJ, as executive vice president and general manager.

Don Winters departs AirTouch Communications, Walnut Creek, CA, as managing director of corporate technology to join Coral Systems, Longmont, CO, as vice president of business development.

Scott Henderson exits Uniden's commercial communications division, Dallas, as vice president of sales to join E.F. Johnson, Burnsville, MN, as director of federal sales.

Elias J. Kabeche leaves The Antenna Company, Itasca, IL, as director of accessory products to join Larsen Electronics, Vancouver, WA, as director of sales and marketing.

Changes at Multiplier, Mt. Kisco, NY:

Al Crisafulli leaves Gemini Industries, Clifton, NJ, as cellular product manager to join Multiplier as product manager for the cellular, GSM and PCS battery and accessory product lines.

Danny Amato leaves Gemini Industries as senior cellular engineer to become senior engineer for Multiplier's cellular, GSM, PCS and two-way, PMR battery and accessory product lines.

Stephen L. Fix departs Ericsson, Lynchburg, VA, as vice president of aftermarket services and parts operation to take a position with Glenayre Technologies, Charlotte, NC, as executive vice president of corporate development.

Marshall Medoff exits Interstate Van Lines, Springfield, VA, as system manager for an assignment with the Industrial Communications Association (ITA), Arlington, VA, as senior programmer in the computer services department.

Robert Corsi, accounting manager for PageNet, Plano, TX, advances to vice president and general manager of PageNet of Philadelphia, Wayne, PA.

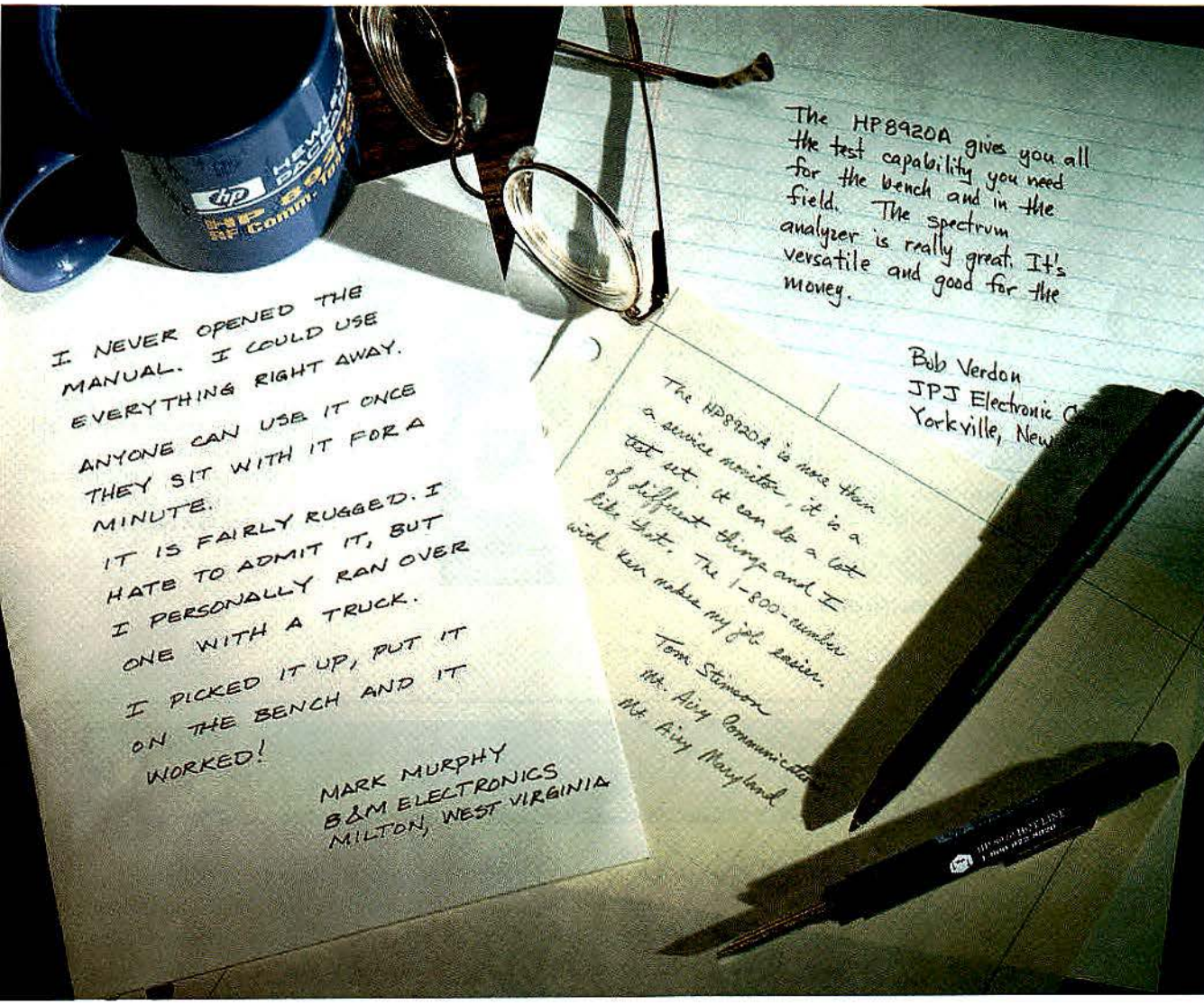
Thomas J. Wiseman, senior project manager for Arcnet, Holmdel, NJ, advances to director of services.

Jack Brophy, president of JBro Batteries, Lisle, IL, is elected to the board of directors of the Portable Rechargeable Battery Association (PRBA), Atlanta.

Robert Trenchard exits Sony Corporation of America, New York, as vice president of management information systems to take a position with Nextel Communications, McLean, VA, as chief technology officer.

Stephen G. Pearse departs Time Warner, Denver, as senior vice president of engineering, operations and MIS to join Geotek Communications, Montvale, NJ, as president of technology and equipment business.

"I never opened the manual for my HP 8920A."



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Either the new HP 8920A RF Communications Test Set is easy to use, or the people who use it are particularly intuitive.

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Circle (73) on Fast Fact Card

Brochure features enclosures

Utility Structures offers a four-page color brochure that shows factory-built, controlled-environment buildings, underground vaults and outdoor cabinets. The company provides everything from small reach-in enclosures to walk-in buildings to partly buried and underground facilities.

Circle (201) on Fast Fact Card

Publication covers trunked radio

The **International Mobile Telecommunications Association's** *Commercial Trunked Radio: Global Overview* answers the most frequently asked questions regarding the trunked radio industry including: What is commercial trunked radio? In which countries is the industry active? What standards have been developed? and Who is a typical customer?

This publication offers an international perspective on the trunked radio industry.

Circle (202) on Fast Fact Card

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TAIT T800

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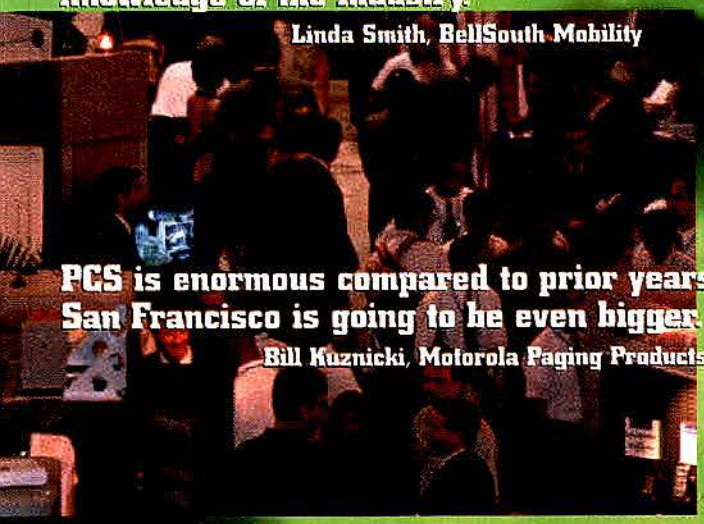
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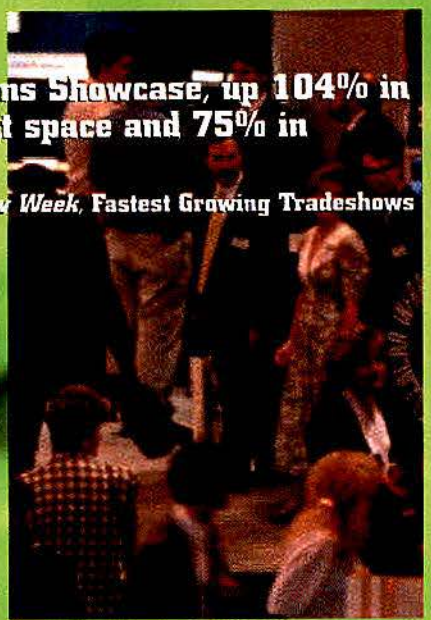
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Linda Smith, BellSouth Mobility



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Bill Kuznicki, Motorola Paging Products Group



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Circle (76) on Fast Fact Card

Two catalogs feature line of passive RF, microwave components

Two catalogs from **Microlab/FXR** cover passive RF and microwave components. The "Wireless Products Catalog" features high-power, low-pass filters; couplers; dividers and tuners for use in wireless signal transmission applications. The "Full Line Catalog" features the entire production and engineering capabilities of Microlab, including attenuators, terminations, dummy loads and couplers.

Circle (203) on Fast Fact Card

Pager handbook is an introduction to paging and a training resource

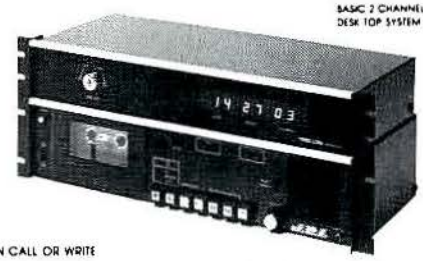
The 124-page text, *Pager Handbook for the Radio Amateur,* is an introduction to paging and a training resource for technicians and sales personnel. Published by **Kantronics,** the handbook describes how paging systems work, how pagers work and gives an introduction to the POCSAG paging code and protocol. The book lists what is needed to monitor paging, investigates the inner workings of a typical pager—both the FM receiver board and the decoder board, outlines procedures for recrystalling pagers and describes how to set up an amateur station for paging.

Circle (204) on Fast Fact Card

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Circle (78) on Fast Fact Card

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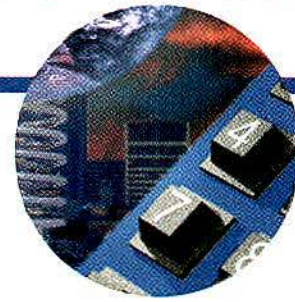
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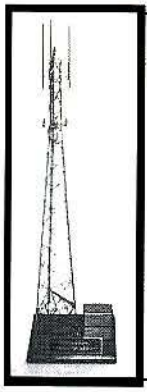
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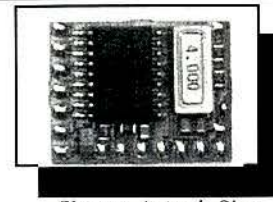
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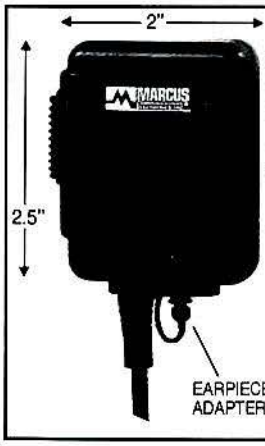
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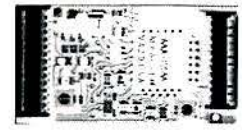
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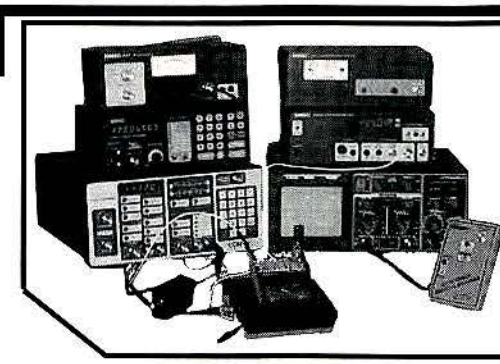
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1	Motorola MTS-800 2 sys. H25JP05170DN	$325
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4	Motorola Mitrek 60w LB 42-50 T51JJA4900BK w/acc	$125 ea
6	Motorola T-1617EM 4f desktop console	$349 ea
10	Motorola Micor Mobile T51RTN1490B 42-50 w/PL & acc	$95 ea
1	Motorola Mitrek UHF 90w PL consolette base	$395
3	Motorola Syntor UHF T445RAJ3004A w/acc	$195 ea
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8 ea.	SPECTRA, 800 MHz, D45KGA5JB7AK
6 ea.	SYNTOR XX, 800 MHz, T45XAJ5G11AK
34 ea.	MOSTAR, 800 MHz, D35TLA5G00DK
3 ea.	MICOR Repeaters, 800 MHz,C75RCBE105BY
2 ea.	MICOR Bases, 460 MHz, B84RCB1105AT
3 ea.	GE MASTR II Bases 460 MHz, VC85RAS8BB
10 ea.	SPECTRA, 460 MHz, M34KMA7JA5AK (Motorcycle)
100 ea.	SYNTOR X 9000, 460 MHz, T34KEJ7J04AK
75 ea.	SYNTOR, 460 MHz, T44SRA3200
24 ea.	MICOR, 460 MHz, T54RTA6903
6 ea.	MICOR, 460 MHz, T54RTA3000
2 ea.	MAXAR 50, 460 MHz, D34JJA3300AK
4 ea.	MAXAR 460 MHz, D34TGA3300DK
36 ea.	SABER, 460 MHz, H440XN7139CN
22 ea.	MT1000, 460 MHz, H44GCU7100
25 ea.	MAXAR Power Supplies
73 ea.	MX300, 460 MHz, H44SSU3140
10 ea.	MT50D, 460 MHz, H34BBU3124
9 ea.	MICOR, 171 MHz, T53RTN3100
17 ea.	SYNTOR, 155 MHz, T83SRA3200
16 ea.	MITREK, 153 MHz, T43JJA6000
6 ea.	PT500, 155 MHz, P33BBM312DAM
5 ea.	P50 Portables, 154 MHz, H33GNU7120AN
90 ea.	MINITOR I Pagers, 155 MHz, H03EAB1212A
2 ea.	SYNTOR X 9000, 47 MHz, T71KEJ7J04AK
24 ea.	MITREK, 47 MHz T81JJA4900
7 ea.	MITREK, 43 MHz, T51JJA4900
226 ea.	MICOR, 47 MHz, T71RTN3100
2 ea.	MICOR Base, 37 MHz, C71RTB1406
6 ea.	Tone Remote Consoles, T1604M
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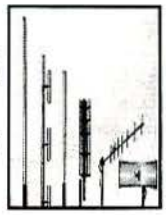
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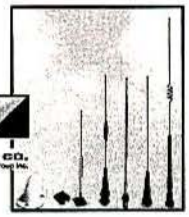
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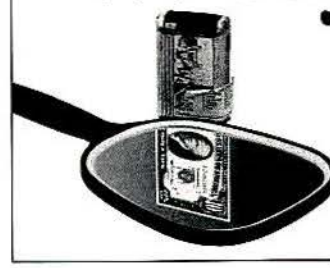
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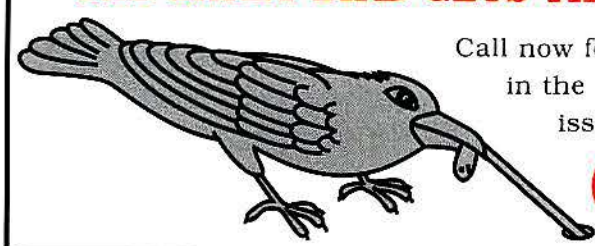
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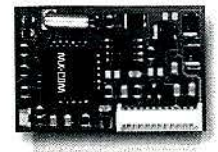
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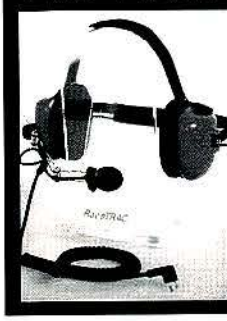
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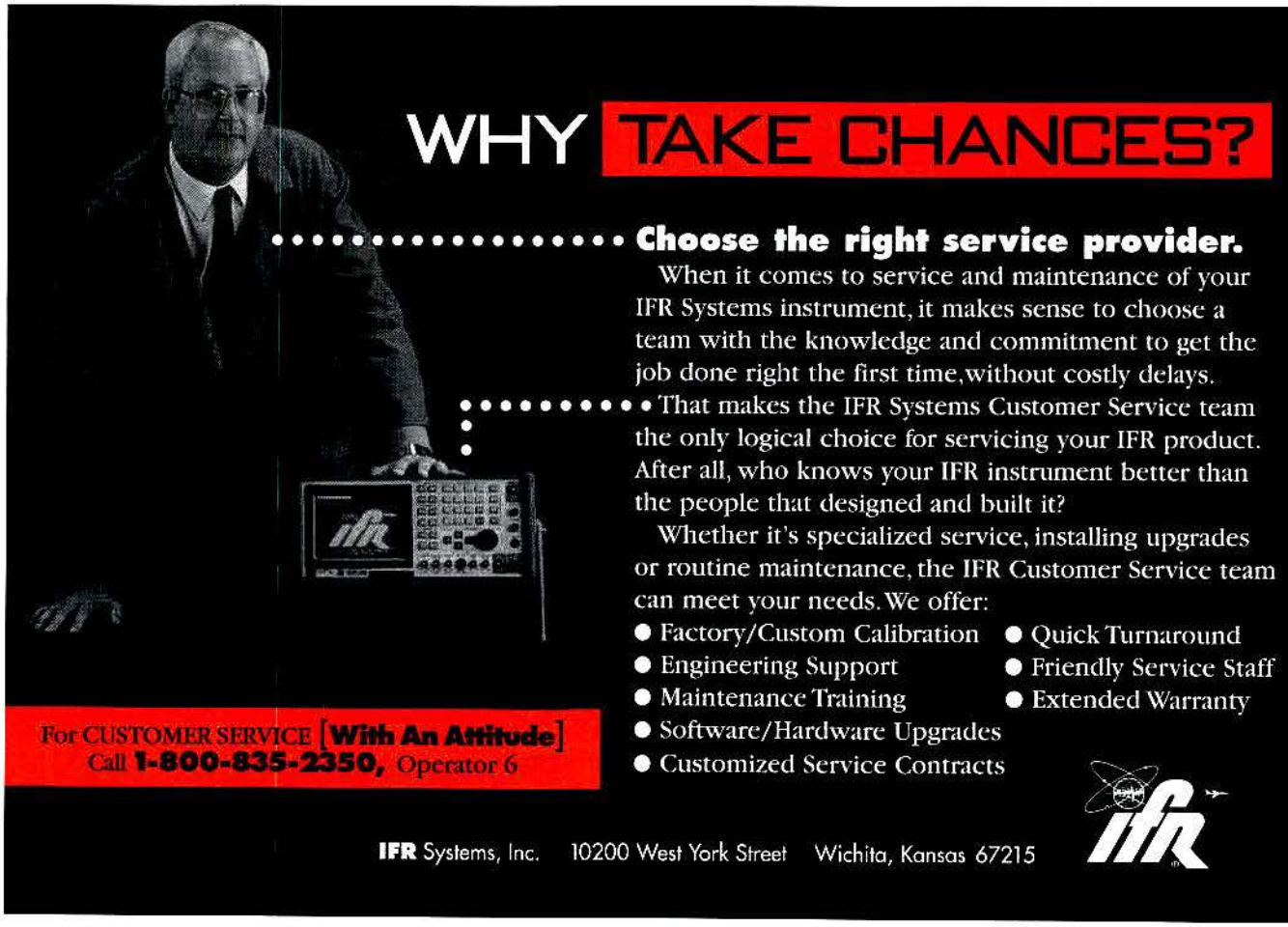


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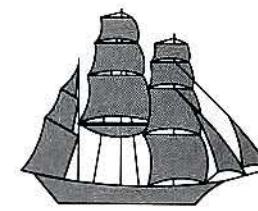
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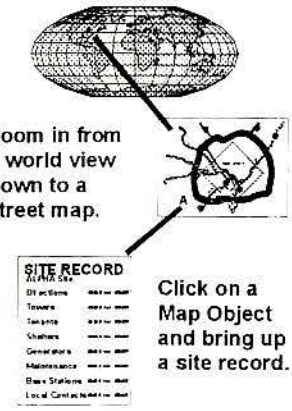
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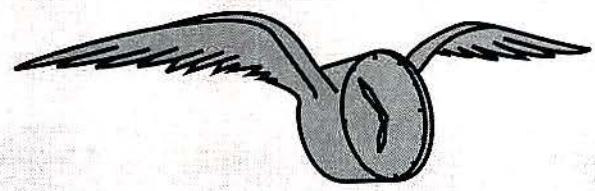
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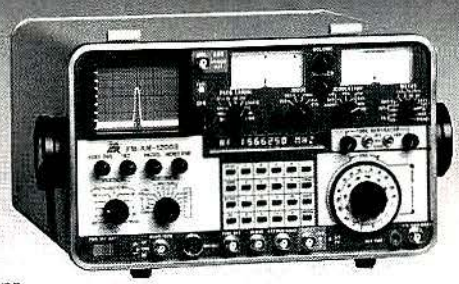


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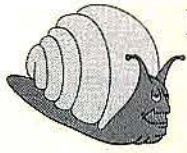
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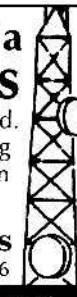
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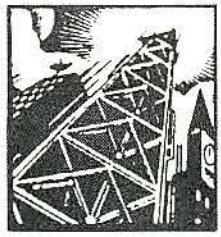
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Cadex Electronics, Inc.	12	8	604-451-7900
Castle Tower Corporation	103	142	800-599-7238
Centurion International, Inc.	7	5	800-228-4563
CEO Tronics	73	69	214-416-9500
Chargeguard Corp.	91	115	800-458-3410
David Clark Co., Inc.	28	20	508-751-5800
Communications Service Co.	95	126	800-875-5109
Communications Specialists	BC	80	800-854-0547
Communications Data Services	99	135	800-441-0034
Communications Instruments	101		970-962-9998
Concept Seating	76	75	414-246-0900
Connect Systems, Inc.	13	9	800-545-1349
Control Signal Corp.	52	45	303-989-8000
CPI Communications, Inc.	56	50	214-437-5320
Crystronics, Inc.	85	104	954-776-0031
CTI Products, Inc.	44	72	513-595-5900
Direct Power & Water Corp	78	78	505-889-3585
D & L Communications, Inc.	96	129	800-336-6825
D & L Communications, Inc.	100	138	800-336-6825
Doppler Systems, Inc.	74	70	602-488-9755
Douglas Integrated Software	100	137	800-845-0408
Duracomm Corp.	40	32	816-746-8300
EAGLE	71	65	520-204-2597
E. F. Johnson	64a-h	58	800-328-3911
EIS Communications	90	114	800-640-6646
Electrocom	54	47	310-946-9493
El Paso Communication Systems	72	66	915-533-5119
EMR Corp.	54	48	602-581-2875
E Trunk Systems, Inc.	87	108	914-245-1128
Fanon Courier	96	128	800-345-1354
Gamber Johnson	59	53	715-344-3482
Glenayre	31	23	770-623-4900
Doug Hall Electronics	38	29	614-261-8871
Havis-Shields Equipment Corp.	38	30	800-524-9900
Hewlett-Packard	75	73	509-921-4001
Hustler, Inc.	49	43	800-949-9490
Hutton Communications	37	28	800-442-3811
Hy-Q International	91	116	606-283-5000
IFR Systems, Inc.	39	31	316-522-4981
IFR Systems, Inc.	98	131	316-522-4981
JBRO Batteries, Inc.	22	16	800-323-3779
J.E.I.	78	77	916-677-3210
JPS Communications	48	42	919-790-1011
Kenwood Communications	45	38	800-950-5005
KNS Electronics, Inc.	101	140	408-432-8100
Larsen Electronics	25	18	800-426-1656
Macaw Electronics	30	22	619-438-2326
Marconi Instruments	55	49	800-233-2955
Marcus Comms & Electronics	88	110	800-833-7724
Marketronics Corp.	17	13	800-845-1230
Maxon America Inc.	10	6	816-891-6320
McManus Communications	85	103	501-763-6250
Mechem Electronics	86	105	540-891-0569
Meridian Communications	29	21	818-222-5655
Micropath Corporation	99		303-526-5454
Microwave Data Systems	72	67	716-242-9600
Midland International LMR	66	60	800-MID-LAND
Modular Communication Systems	32	24	818-764-1333
Motorola Test Equipment	5	4	800-505-TEST
MX-COM, Inc.	97	130	800-638-5577
Myrtle Beach Communications	94	121	803-448-7734
Noise Cancellation Tech.	43	35	203-961-0500
NSI, Ltd.	94	120	206-946-2426
Onyx Wireless Laboratories	93	119	714-374-2828
Optaphone Systems	44	36	707-923-4000
Orbacom Systems, Inc.	41	33	609-829-4455
Peiker Acustic, Inc.	65	59	916-888-3771
Personal Comms Industry Assn.	77	76	703-739-0300
Pirod, Inc.	46	39	219-936-4221
Polaris Industries	95	125	800-752-3571
Polyphaser Corp.	63	56	800-325-7170
Radio Wholesale	88	109	800-53-RADIO
Ramsey Electronics	92	118	800-446-2295
RCW Distributing	90	113	800-726-9015
RELM Communications	47	41	800-821-2900
Ritron, Inc.	69	63	800-USA-1USA
RMS Communications	95	127	800-627-2022
Serviceware Corporation	46	40	819-770-4000
Sharp Communication	94	122	800-548-2484
Shure Brothers, Inc.	19	15	800-25-SHURE
SoftWright	99	133	303-344-5486
Sonic Communications, Inc.	14	10	800-688-1944
Spectrum Communications Corp.	71	68	610-631-1710
STi-CO Industries, Inc.	62	55	716-662-2680
Survey Technologies, Inc.	60	54	503-591-5986
Tait Electronics USA, Inc.	76	74	713-984-8684
TCS Consultants, Inc.	80	100	409-588-3200
Telepath	16	12	510-656-5600
Telepoint, Inc.	68	62	310-652-3666
Telewave, Inc	53	46	415-968-4400
TESSCO	21		800-472-7373
TESSCO	23		800-472-7373
Transcrypt International Ltd.	3	3	800-276-8799
Trident Micro Systems	67	61	800-798-7881
Tripp Lite	58	52	312-755-8741
Trylon Mfg. Co. Ltd.	74	71	519-669-5421
TX RX Systems, Inc.	11	7	716-549-4700
Vega, A Mark IV Company	1	2	818-442-0782
Vertex/Yaesu USA	IBC	79	310-404-2700
Vocom Products Company LLC	18	14	800-USA-MADE
Wandel & Goltermann, Inc.	64	57	919-460-3316
West Coast Radio	86	106	310-268-2464
Wetec Electronics	88	111	888-469-3832
Wetec Electronics	91	117	888-469-3832
Wireless Resources	98	132	800-409-4509
Wireless Resources	102	141	800-409-4509
WirelessWorld Expo '96	84	102	800-288-8606
Zetron, Inc.	42	34	206-820-6363
Zetron, Inc.	51	44	206-820-6363
Zetron, Inc.	57	51	206-820-6363

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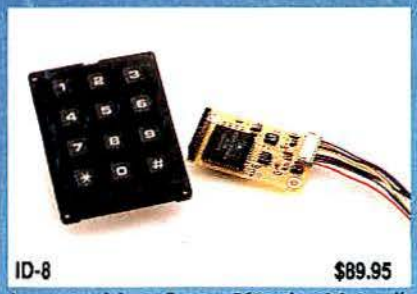
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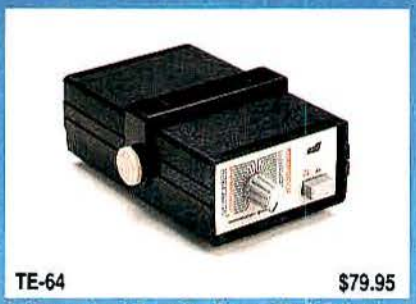
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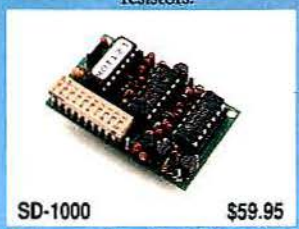
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